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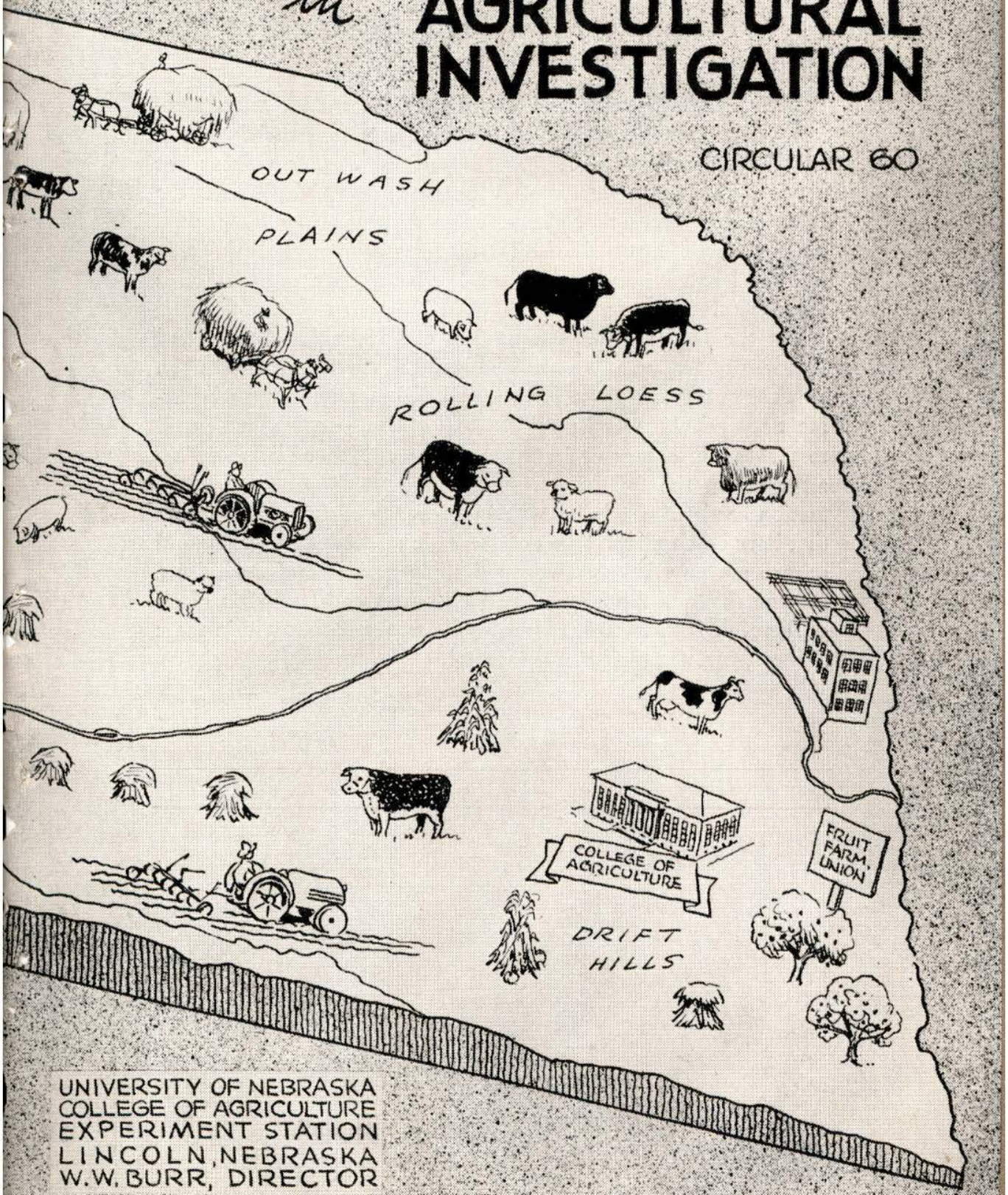
Fifty Years' Achievement in Agricultural Investigation

R. T. Prescott

60

50 YEARS OF Achievement in AGRICULTURAL INVESTIGATION

CIRCULAR 60



UNIVERSITY OF NEBRASKA
COLLEGE OF AGRICULTURE
EXPERIMENT STATION
LINCOLN, NEBRASKA
W. W. BURR, DIRECTOR

FOREWORD

THE PAST FIFTY YEARS have witnessed the transformation of Nebraska from a pioneer state to a thriving commonwealth with established traditions. Her citizens are engaged in a great variety of occupations, but agriculture is the basis of her prosperity. These years have been marked with notable developments in land settlement, agricultural progress, industrial and business enterprise, home building, and economic adjustment.

At the beginning of this period, the Nebraska Agricultural Experiment Station was organized and has since been relied upon by citizens of the state to carry on needed research for the betterment of agriculture and rural life. After fifty years it may be well to take an inventory of its accomplishments. Some of these are set forth in the following pages. It will be apparent that the Station has been closely identified with many of the advancements that have taken place. Many of the basic principles of agricultural science are now better understood. The problems of agriculture are complex and the Station cannot undertake the solution of all of them. It is limited, of course, by its resources, but within these limits it can accomplish a great deal.

W. W. BURR, *Director*

Lincoln, Nebraska *March, 1939*

Fifty Years' Achievement in Agricultural Investigation

By R. T. PRESCOTT, *Agricultural Editor, in Collaboration with the Technical Staff and with the Aid of Pearl M. Nelson*

EXPERIMENT STATION CIRCULAR 60

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UNIVERSITY OF NEBRASKA COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

C. E. Bessey, first director of the Nebraska Agricultural Experiment Station. Dr. Bessey came to the University as Dean of the Industrial College and professor of botany and horticulture in 1884, helped write the federal Hatch Act, outlined and directed the early work of the Experiment Station, and promoted the study of plant diseases, forestry, and many other agricultural sciences.

The Beginnings

FIFTY YEARS have passed since the Nebraska Agricultural Experiment Station was organized. At approximately the time of its organization—the late 1880's—experiment stations were also established in the other "land grant" colleges and universities of the country, under the provisions of the national Hatch Act of 1887, which created agricultural experiment stations.

The "land grant" colleges, also a part of this national plan, had been provided for previously by the Morrill Act of 1862. These colleges were supported by liberal grants of public land and were characterized by the stipulation that they were to include agriculture and the mechanic arts, hitherto unknown in college curricula, as part of the regular courses. The University of Nebraska became a "land grant" college when it was established in 1869.

One of the important objects, in addition to providing educational facilities, was to aid agriculture. But during the interval between the sixties and the eighties it became apparent that some provision must be made for investigative work—for research in both field and laboratory to assist the colleges. The botanists, chemists, geologists, and physicists, as well as the professors of agriculture, who had been employed to teach, found little time and only meager facilities for investigative work. Some efforts at investigation were made. At the University of Nebraska a farm was purchased, a few experiments were tried, the idea of a model farm was considered, an animal-disease laboratory was set up. But the problems of agriculture, the losses from crop failure, losses from animal diseases, and the destruction due to pests were acute and needed more thorough study.

Other factors were also influential in the establishment of experiment stations. Populations were increasing rapidly in many of the temperate regions. Because of immigration and wealth of new opportunities this was especially true in the United States. Developments in manufacturing, communication, and transportation had speeded up during the previous half century. America's agricultural plant had recently been expanded to include the western Great Plains. In Nebraska the population increased from a half to a full million during the eighties.

Another factor was the rapid development of the sciences during the nineteenth century. Louis Pasteur had accomplished the feat of immunizing livestock against anthrax and had made other equally important discoveries. Lord Lister had demonstrated the practical use of antisepsis in surgery. In the early eighties, Robert Koch had put bacteriology on a

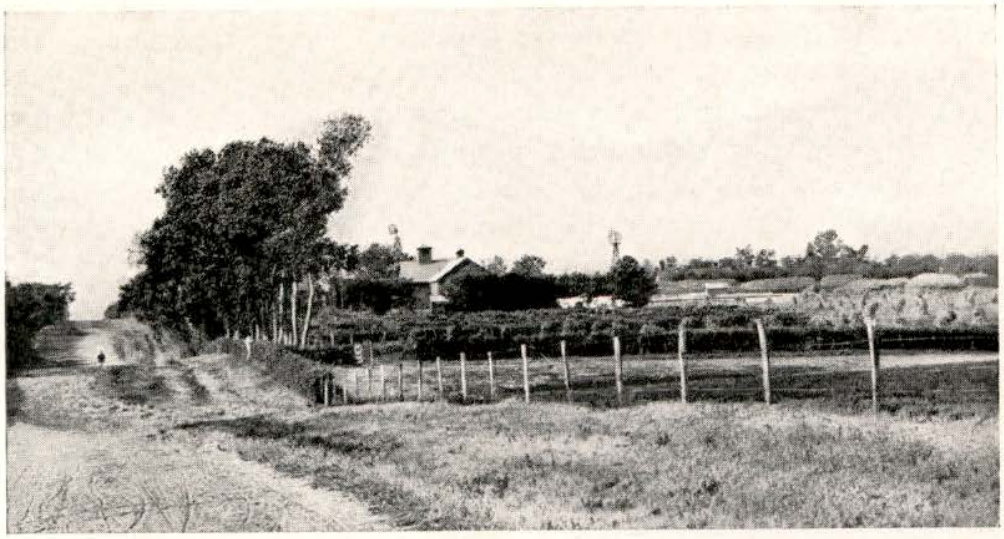
scientific basis. Other great names were being made in scientific research at the time, and science, as applied to health, industry, transportation, agriculture, seemed to be the great benefactor, the great new means of increasing wealth and human happiness.

In Nebraska, a hustling frontier state in 1887, the legislature hesitated not at all in taking advantage of the provisions of the Hatch Act, and now that fifty years have elapsed since the Station was founded, seventy-five years since the Land Grant College Act was passed and the U. S. Department of Agriculture established, and almost twenty-five years since the Agricultural Extension Service was added, it seems worth while to present a general summary of achievement within the state.

Courtesy Nebraska Historical Society.

Farm scene in Custer County, 1886.

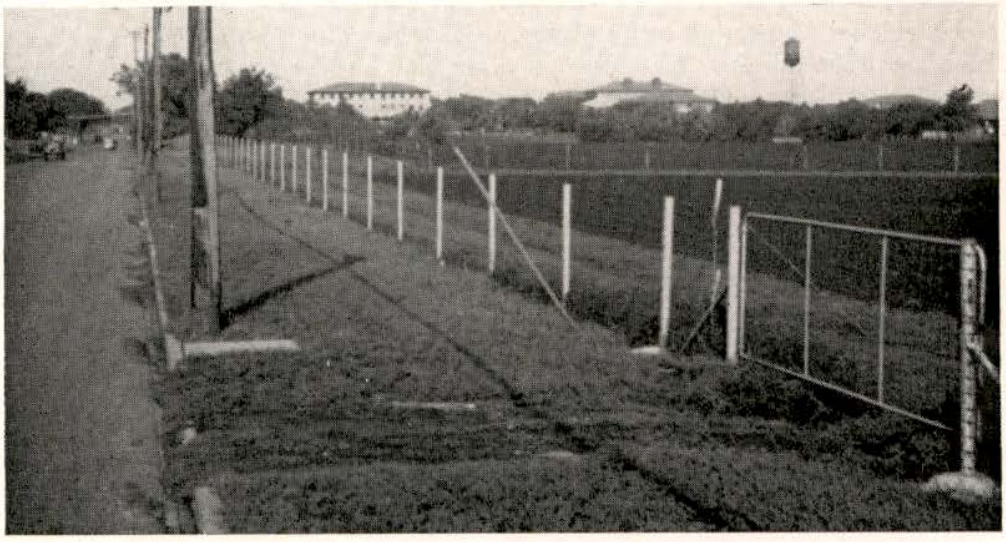
The main object will be to show some of the important things that have been learned through the investigations of the Station over a period of fifty years. To many readers of agricultural college publications, some background information may be helpful. But it should be remembered in this connection that no investigative or research institution, no individual research worker, can ever be said to be working alone. Each individual, each laboratory—whether of an endowed foundation, state university, private university, or industrial corporation—makes but contributions in fields where others work. In fairness it must be said that a large part—by far the largest part—of the agricultural research work carried on in the states has been initiated and carried on by the experiment stations. But without the cooperation of all interested groups, including farmers



Early picture of the Experiment Station farm at Lincoln

and business men, and without the aid of scientists elsewhere, these stations could have made little progress.

A scientific research worker is simply an observer, one who has been trained through many years to see and understand what he sees. As a specialist he must limit his attention to a narrow range of subjects. Because of this fact scientists are, as a group, heavily dependent upon each other, and the trends have been toward greater cooperation, more regional planning of research, a greater number of outlying substations or experimental farms, more cooperative demonstration tests among farmers.



The Nebraska College of Agriculture from the same point of view as it appears today.

During the early years, as might be expected, there were many problems of planning and organizing. In 1887 the University of Nebraska enrolled fewer than 500 students and the work of teaching was done in a small group of buildings on only a few acres of ground. The 320-acre farm

that is now the location of the College of Agriculture had been purchased in 1874, but the distance from the University, almost three miles, was a serious handicap then.

Despite its small size, as compared with its size at present, the University had a group of well-trained scientists on its staff, who assumed the responsibility of organizing the Station and directing the first researches. The animal-disease investigations, begun in 1885 and supported by the state, were incorporated into the new Station organization. Dr. C. E. Bessey, dean of the Industrial College (there was no College of Agriculture at the time), became the director and within a short period found time to publish, as a bulletin, some studies by himself and his students on rusts, smuts, and other plant-disease fungi in the state. Lewis E. Hicks, a geologist, published the first bulletin, a survey of the possibilities of irrigation in the state. Conway MacMillan and Lawrence Bruner published early bulletins on insects, and Frank S. Billings, the animal-disease investigator, published on "swine plague" (cholera), "Southern cattle plague," and other diseases. Within a few years the first field experiments, conducted at the farm, were ready to be reported and in 1890 the first climate study, by DeWitt B. Brace, was published.

Thus, with few facilities, comparatively small appropriations, little knowledge of the state's climate, less knowledge of the soils, only hazy ideas of adapted crops, and with serious threats from animal diseases, insect pests, and plant diseases, the Station workers set out to apply science to 80,000 square miles of Great Plains territory.

Readings In Agricultural History

Agricultural history has many phases, such as the early history of crops, the early history of livestock, and the history of tools and implements. Scientific research in agriculture is recent. Almost anyone can enjoy Carrier's "Beginnings of Agriculture in America" (McGraw-Hill, N. Y., 1923); this deals with the early history of crop plants, livestock, machinery, tools, and other matters, and also includes a list of publications related to the subject.

Important also is A. C. True's "A History of Agricultural Experimentation and Research in the United States, 1607-1925" (Misc. Pub. 251, U. S. Department of Agriculture, Washington, D. C.). This reports the development of agricultural research in the United States and in addition contains an extensive list of historical materials.

"These Fifty Years," by R. P. Crawford (Nebraska Experiment Station Circular 26), is a history of the College of Agriculture of the University published in 1925. A. E. Sheldon's "Land Systems and Land Policies in Nebraska," published in 1936 by the Nebraska Historical Society, State Capitol, is closely related to agricultural history. Good sources for those interested in finding historical facts are the annual reports of the experiment station and reports of agricultural boards and societies.

A general book on agriculture especially adapted to schools is Bradford and Spidel's "Nebraska, its Geography and Agriculture" (Macmillan, N. Y., 1934). Another is Condra's "Geography, Agriculture, and Industries of Nebraska" (University Publishing Co., 1935).

Climate

IN SPITE of the fact that many settlers had lived in Nebraska or the Nebraska territory for thirty years, information of an accurate sort on the state's climate was scanty in 1887. Despite first-hand experience, no one knew enough about the climate to make a really accurate description of it. Dr. Bessey urged that weather records be kept "at all hazards." "I need not enter into an argument," he said in the first Station report, "to prove the usefulness of such work."

In keeping with the times interest was increasing in accurate weather knowledge, and devices for recording were being improved. Some records had been kept, of course. The oldest records available are those kept at Fort Kearney, and date back to 1849, and there are other early records that were kept by officers at forts or by farsighted citizens. The present federal Weather Bureau, a part of the U. S. Department of Agriculture, was organized in 1890, when its work was transferred from the Signal Corps of the U. S. Army. During the late 80's and early 90's Nebraska had a state weather service, located at one time at Crete, and at another in Omaha. In 1894 it was moved to Lincoln and became a part of the Experiment Station. At this time G. D. Swezey, of Doane College, came to the Station as meteorologist. Then in 1896 all the meteorological work was placed under the administration of the U. S. Weather Bureau, although the office was not moved.

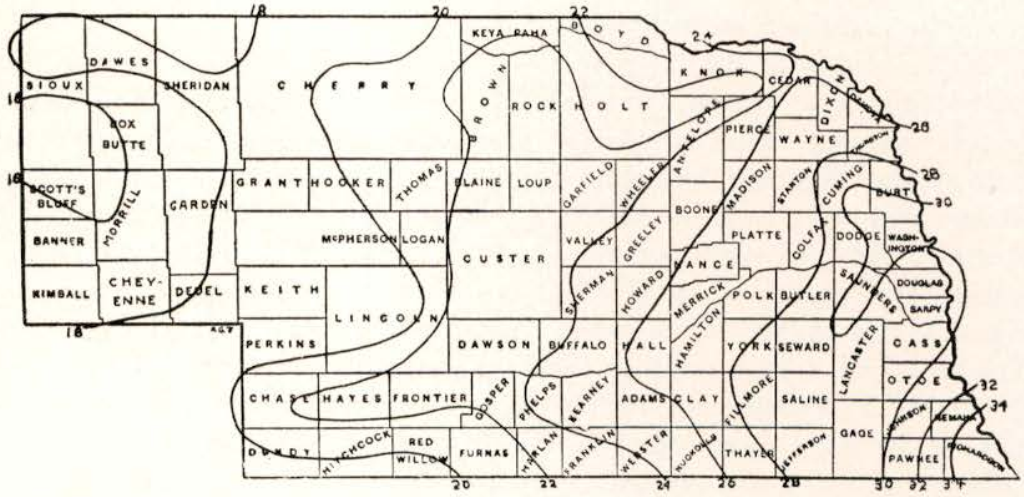
The Nebraska Experiment Station, then, had a brief but important part in the history of climatological studies in Nebraska. During the first years elaborate summaries of the records kept in Lincoln were published annually as Station bulletins, by DeWitt B. Brace, the University physicist who had been made a member of the Station staff. It would tax the reader's patience to describe these reports in detail but it should be mentioned that recording and compilation were not light tasks, and today as then, we who read forecasts and consult weather summaries do not realize the time and patience required to bring the great mass of information into compact, intelligible form.

Reports were published monthly for a time, telegraphic forecasts were received from Chicago, flag signals were displayed, and reports were distributed daily. The number of volunteer observation stations was increased, thus making possible a wider distribution of records. What was most important, probably, was the publication of a bulletin, entitled "The Rainfall of Nebraska," in which Mr. Swezey summarized and interpreted the information that had up to that time become available. Coming at a time when the state had gone through one of its worst periods of drouth,

it served to correct some popular opinions and to increase popular appreciation of scientific studies.

There are many questions yet to be answered about climate. And then there is always the question, Will the questions *stay* answered? From present information it is possible to provide a practical, working knowledge of climate in an area like Nebraska where records from a large number of observation stations now run back over more than half a century.

Accurate knowledge of climate is useful to farmers since it aids them in estimating the adaptability of certain crops and provides a general notion of the probability of crop failure. It is also of inestimable value to others. Eventually long-range forecasting may become a more reliable science, but at present the records of the past are the best guides for the future.

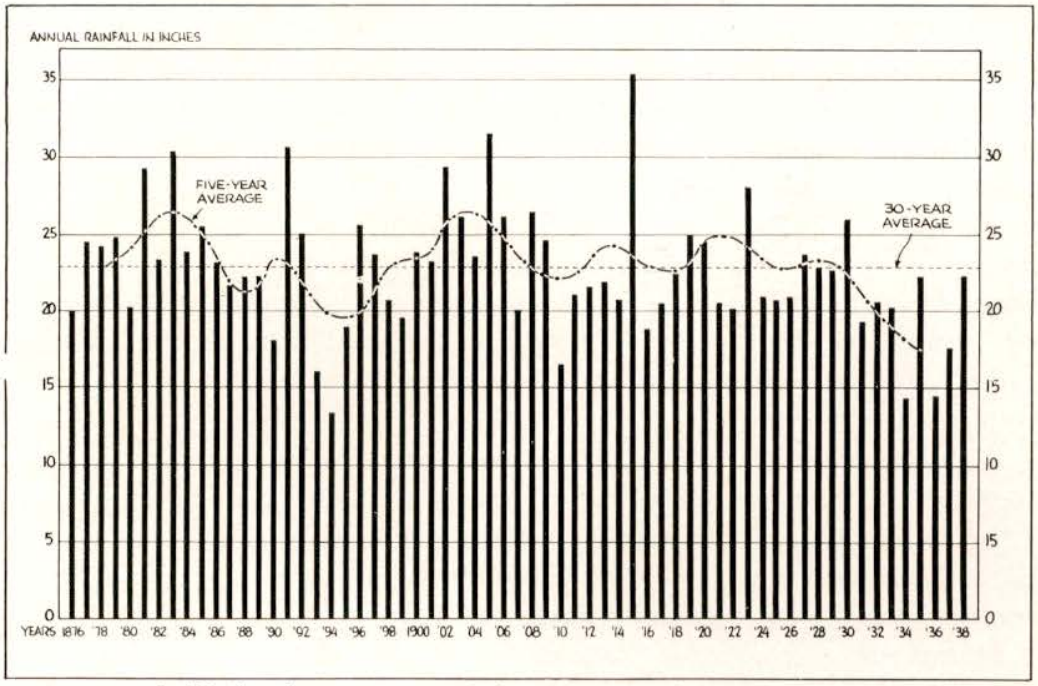


Distribution of average precipitation in Nebraska.

Climatic factors are of the deepest significance in any estimation of the suitability of a region for human life. Precipitation, temperature, length of growing season, evaporation, humidity, and the nature of storms are factors that in a sense determine plant and animal life. Weather makes soil out of rocks, makes vegetation possible, influences the kinds of vegetation, influences also the animal life that thrives in an area. Under a given set of conditions of climate and soils—for example the Nebraska area before white people came—changes in plant and animal life take place slowly and may be said to be adaptations to the conditions as they exist. In addition the climate and soils are undoubtedly changing, though the extent and nature of such changes are not fully understood. Among these factors— climate, soils, plants, animals—we recognize climate as a direct, powerful influence on our welfare, one beyond our control, one to which we must adapt ourselves. Soils, crops, livestock, physical comforts, and economic conditions can be changed, but not the climate.

Of all climatic factors, precipitation is the one that receives the most attention, and nearly everyone is familiar with the fact that in Nebraska annual precipitation diminishes toward the west. A glance at the rainfall

map will show the distribution. One should remember that in elevation Nebraska rises toward the west. The Platte River, in its meandering course, falls at the rate of about seven feet per mile. If one were to traverse the state from east to west in four great steps of about 100 miles each, he would rise about 1,000 feet with each step. Near the western edge of the Nebraska "panhandle" he would be standing at an elevation



Average rainfall for the state as a whole. The vertical bars show annual rainfall. The curved line shows five-year averages. The straight horizontal line shows a 30-year average.

of about 5,000 feet above sea level and would be about five times as far above sea level as he was when he started. At this point the rainfall averages approximately half what it is in the eastern part of the state, as the map shows.

There are other changes in climatic conditions from east to west in Nebraska and to a less extent from south to north—changes that are reflected in the vegetation and in the types of farming. At the northwestern corner the frost-free period is about 120 to 130 days, beginning near the middle of May and ending about the middle of September. At the southeastern corner farmers can count on an additional six weeks or two months. Their season begins ordinarily in late April and ends in October.

Changes in temperature also occur. Average annual temperature declines from approximately 54° F. in the east to 44° F. in the west. The hazards of temperature are chiefly two—hot winds and frost. Both are well known in Nebraska.

The records of average annual precipitation shown in the graph are perhaps the most interesting of climatological data. One notes that though the average precipitation for the state for 61 years is between 22 and 23

inches, the yearly precipitation has varied from as much as 13 inches above this average to 9 inches below. Only about a third of the years have really been as high as average. It is noticeable also that periods of several years of drouth recur.

Drouth is the great hazard, and not only the long periods of drouth but also the short period, thirty days or more in length. Climatologists have noted the occurrence of periods of 30 days or more without as much as a quarter of an inch of rain from March 1 to September 30, and here also there is a change toward the west in Nebraska. Such drouths average about one in two years for the eastern part compared with two per season in the western. This is true despite the fact that most of the annual precipitation occurs as rain during the growing season.

Humidity and the rate of evaporation from a water surface are other factors. Relative humidity averages from 5 to 10 per cent lower in the western than in the eastern part. Evaporation rate is highest in the central part and lessens slightly toward both east and west. During the growing season, April to September, from 35 to 45 inches of water will evaporate from a water surface.

All of these factors, the rainfall, the temperature, the humidity, and the length of the frost-free season are correlated with the fact that vegetation in the eastern part of the state is more luxuriant than it is farther west—hence the irrigation and summer fallowing in western areas and also the types of farming these practices require.

Storms are a conspicuous feature of the Nebraska climate. There are many kinds—the tornado, the hailstorm, the blizzard, the duststorm, the cloudburst. Each is destructive in one way or another, and all are more or less generally known. The most destructive is the hailstorm and its distribution has been studied. The central and western parts of the state are somewhat more subject to such storms than is the eastern part. Sudden, heavy downpours of rain are especially destructive in rolling areas because of the erosion they cause.

In 1896, G. D. Swezey, writing during a period of drouth, explained in his bulletin on rainfall that such periods are to be expected in Nebraska. Basing his opinion on the records then available he pointed out that the "period from 1859 to 1862 was a similar period of drouth here in Nebraska, the rainfall of all these four years being below the normal and that of 1860 being probably almost as small as that of 1894, although records are too meagre to give exact averages."

In 1937, J. B. Kincer, of the U. S. Weather Bureau, speaking during another drouth period, said that doubtless, when the present drouth should come to an end, "there will be a period of years with comparatively heavy rainfall, just as before, and little will be heard of duststorms and the like. But, in planning a permanent farm program for such areas, the basic consideration should include the practical certainty that dry climatic phases, at least as severe as in the past, will recur."

References on Climate

Climate may be studied by consulting good atlases, such as the "Atlas of American Agriculture" (U. S. Department of Agriculture, 1936). This is a large and expensive atlas and should be available in the larger libraries. The U. S. Weather Bureau publishes summaries of climatic records for areas, for example, "Climatic Summary of the United States, Section 39, Eastern Nebraska" and "Section 38, Western Nebraska." Write to the Superintendent of Documents, Washington, D. C.; the price is 10 cents each (stamps not accepted).

There are good books on climate; examples are Blair's "Weather Elements" (Prentice-Hall, N. Y., 1937) and Kendrew's "Climate" (Oxford Univ. Press, 1938).

Bulletin 45, "The Rainfall of Nebraska" published in 1896 by the Nebraska Agricultural Experiment Station is out of print, as is Extension Circular 14, "The Climate of Nebraska," but copies can be seen in the larger public libraries. There are many popular books on geography and natural science that have portions devoted to climate.

A series of maps showing the distribution of temperature and precipitation in Nebraska may be obtained from the Department of Geography, University of Nebraska; the price is 25 cents for the series.

Nebraska Soils and Their Management

OF MAJOR interest to the scientists of the early Experiment Station were the soils of the state. Of the dozen "scientific" (as distinguished from "popular") experiments, which were recommended by Director Bessey, eight were concerned with soils. They included observations on soil temperature, soil humidity, percolation of water through soils, chemical and physical analyses of soils, fertility, porosity, and irrigation. These were recommended as of major importance in 1885, when the University farm was being cleaned up preparatory to experimental studies. With the establishment of the Station in 1887, some of these were put into operation.

The purpose of most of these studies was to bring to light some of the fundamental facts about conditions within the soil which aid or hinder plant life. At this time there was no specialized soils science such as we have today—no extensive knowledge of the chemistry, structure, and origin of soils and much less knowledge of soil biology and of the processes of change that are constantly going on in soils. Out of the older sciences of geology, chemistry, physics, and biology, a new soils science was coming. It has made rapid progress and is fundamental to an understanding of agricultural problems in general. Many practical problems have been solved—problems related to soil moisture, fertility, harboring of plant-disease organisms, erosion, and others. Many are still in the process of being solved.

To the scientists, soils are of infinite variety. To the home-seekers who flooded over the Nebraska land in the 70's and 80's, the variations were less apparent. Wisely and shrewdly the homesteader observed the vegetation, measured sunflower stalks, kicked in the soils with his boot, and observed colors and textures. The native grasses, luxuriant and undisturbed for ages, had enriched the soils with organic matter and had improved their moisture-holding capacity through the accumulation of plant debris. The tough fibrous plants of the prairie sod held the soil in place and controlled erosion. Springs and streams flowed evenly and clearly. Native shrubs and trees grew along streams and in places protected from prairie fires. These facts and factors made Nebraska soils seem uniform to the home-seeking eye—uniform in what the land-use planning specialists now call "use suitability."

The farming experience of more than half a century has shown how widely these soils differ from each other. Underneath their covering of grasses, the differences in physical character, in depth, permeability, and other structural characteristics were not apparent. The grasses protected

the slopes from erosion and made the importance of slope less apparent to the settlers. Farmers learned early that continued use of a few crops (corn, wheat, and oats were the popular trio) would never do, even though these crops had once yielded well. Loss of organic matter (those parts of the soil that are of plant or animal origin), loss of stored moisture, and increase in the tendency to erode became noticeable. Briefly stated, the change from the native grasses to continuous cultivation has made the problems of moisture, fertility, and erosion of utmost importance.

The early, fundamental work of the Station included an extensive survey on the possibilities of irrigation in the state. This survey, published as Bulletin No. 1, aroused interest in irrigation from the North Platte

Soil profile revealed in a road cut in northern Knox County. At right is the top of an ancient hill of glacial drift, and upon this a loess cap was later deposited by wind. A dark layer of top soil may be seen at the upper right.

and other rivers. In 1899 Professor E. H. Barbour completed his bulletin on the "Homemade Windmills of Nebraska," a widely popular publication dealing with irrigation by means of windmill pumps. At the Station farm a windmill and earth reservoir were used for a time to irrigate truck crops. During the same time, University men were industriously collecting samples of the soils of the state, and in 1898 an exhibition of three-foot samples won a medal at the Trans-Mississippi Exposition in Omaha.

All of this work was preliminary, leading toward more systematic, more comprehensive knowledge. Studies of wells in cooperation with the federal Geological Survey were begun in 1895. The federal Soil Survey,

an undertaking that has reached considerable size and has yielded results on a large scale, was begun in Nebraska in 1903. Soils in all counties except a few in the sandhill area have now been surveyed, and about 400 types and phases of soils have been recognized. Classification of land into five grades in accordance with productivity has been completed for all counties.

In the University of Nebraska a Division of Conservation and Survey was established in 1909 by the state legislature. Since its establishment, this organization has been under the direction of G. E. Condra, and among its duties have been those of studying the state's natural resources and underground water. The Division has cooperated also with the federal Soil Survey.

The surveying, the collection of samples, the observations of irrigation possibilities, the analyses, the experiments on tillage—in fact all of the work of the first 20 years—were sufficient to guide the Station workers in certain directions, to test certain methods, to make some beginnings. With increasing attention to soils, there was a gradual improvement in methods of study. A genuine science of soils was coming into being.

A factor that stimulated the study of soils in Nebraska and adjacent territory was the inadequacy of moisture for continuous production of abundant crops. It was repeatedly pointed out in agricultural bulletins and the journals of the period that ways must be found of adapting crops to the limited rainfall. The coming of winter wheat helped, for winter wheat is a crop that makes its greatest growth during the seasons of most precipitation. Sorghums were another answer, and they were advocated then, as now, as a means of insuring feed in years of crop failure due to drouth. But crops were not the only remedy searched for; ways of tillage were also considered.

On the Station farm at Lincoln and among cooperating farmers in the various sections of the state, tests were being made in the 1890's of depth of plowing, subsoiling, and other practices that would "save every drop." Many of the results were inconclusive. For example, subsoiling (stirring the subsoil at depths of ten inches or more) seemed at times and under certain conditions to offer advantages, but again it did not. The early tests showed that more tests were necessary—tests that could be more carefully controlled so that the influences of factors other than those to be tested could be eliminated. Substations cooperatively sponsored by the state and the United States Department of Agriculture, and distributed over the state, were considered and several had been established by 1912. Long-time tests were planned that could be averaged over long periods of years—so that clear proof of the advantages and disadvantages of a practice could be demonstrated.

A question of fundamental importance was the question of what happens to moisture that soaks into the soil. In 1898 T. L. Lyon, of the Nebraska Station, probably represented current opinion when he said in an article in the *Nebraska Farmer* that water will do one of three things:

it will move toward the surface of the soil and be lost by evaporation, it will run off the surface, or it will percolate down and perhaps reappear in springs. There was apparently some mystery about the direction of movement of moisture in the soil. Summer tillage—that is, alternating crop years with years of clean fallow—was coming to be recognized as successful in the western plains areas. The question was: Can moisture be stored in the soil from one year to another, and if so, to what extent?

W. W. Burr, Director of the Experiment Station and Dean of the College of Agriculture, University of Nebraska. His earliest work for the Station consisted of investigations of soil moisture.

After about seven years of collecting soil-moisture data at the North Platte Substation, W. W. Burr in 1914 came to the conclusion that moisture stored below the first few inches will largely "stay put" unless removed by plants, whether crops or weeds. The capillary movement, so commonly compared to the movement of oil in the lamp wick, he found to be of considerably less importance than many had supposed. We are accustomed to saying now that soil will retain its carrying capacity of moisture from

one year to another or until removed by the roots of plants. Roots must reach into the moist layers of soil, because that moisture will not come to the roots. Deep-rooted plants like alfalfa, bindweeds, and trees will survive where more shallow-rooted plants cannot.

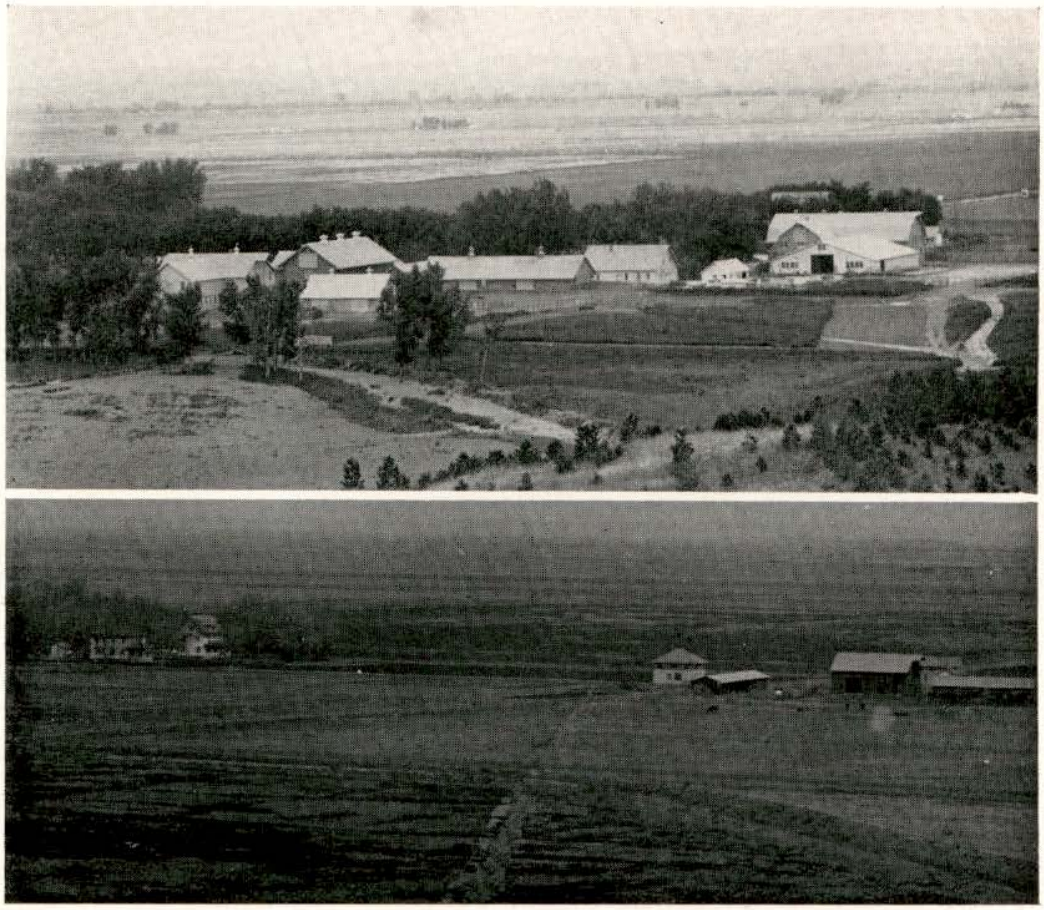
Burr was working with W. P. Snyder, superintendent of the North Platte Substation which had been established in 1904 especially for the purpose of aiding those farmers who had migrated into the high, subhumid, semiarid country of central and western Nebraska. While Burr and Snyder were working at North Platte, F. J. Alway, chemist at the main station at Lincoln, was reaching similar conclusions from the study of soil in buried cylinders, and in other stations and other parts of the world similar investigations were going on.

These studies of soil moisture have had important relations to tillage practices and rotations, and to the problem of winter cover and blowing soil; in fact they are fundamental to any study of moisture conservation. Determinations of stored moisture are now used in forecasting yields of crops, especially winter wheat. Modifications of the summer tillage practice have proved beneficial at North Platte; for example, tillage immediately after the harvest of winter wheat has proved helpful in conserving moisture and improving prospects for a successful crop the following year. Intertilled crops such as corn and potatoes do not deplete moisture to the extent that wheat, oats, and other close-drilled crops do.

In eastern Nebraska the same general principles have been demonstrated in soil-management tests. For here, though to a less extent than in western Nebraska, the "limiting factor," as it has so commonly been called, is moisture rather than fertility. In Nebraska, an area where the soils were once part of an ancient sea bed and where ice, water, wind, and various forms of life have worked throughout the geological ages, the soils are naturally fertile and for the most part are well adapted chemically and physically to crop production.

Early tillage of a field has been found in eastern Nebraska to be effective in increasing yields, in comparison with treatment (plowing, listing, or disking) only a short time before planting. A predominant part of the work with cropping practices at Lincoln has been directed by T. A. Kiesselbach, whose work covers approximately 25 years. The reason here, as in western Nebraska, is control of weeds and prevention of loss of stored moisture. Fall plowing for spring sown crops has not been found beneficial in eastern Nebraska, so far as yields are concerned, and the explanation seems to lie in the fact that overstimulation of crop growth occurs early in the growing season on fall-plowed land, with the result that when July and August come along the stored moisture is less plentiful than with early spring plowing. Besides, fall plowing is subject to blowing in an open winter. Here, we note, it is the climate—the winter winds, the spring rains, the late summer drouth, and the high July and August temperatures—that must receive major consideration in the selection of soil-management practices.

At two other substations, the Scotts Bluff Substation and the substation at Valentine, soil management has also been considered. At Valentine varieties have been tested on "hard land" but all attempts at cropping on the sandy land have been abandoned. At the Scotts Bluff Substation (under cooperative state and federal management) elaborate and highly significant rotation experiments under irrigation have been in operation for almost 30 years. Under irrigation the "limiting factor" becomes fertility rather than moisture. The rotations vary from continuous cropping with a single crop to rotations seven years long. The chief comparisons are



Two views of the North Platte substation taken from the table land: above, 1936; below, 1911.

comparisons of the rotations with and without manure and with and without legumes. The history of the yields in these plots is the history of what may be expected elsewhere—a history of changes in fertility, in soil-borne disease organisms, in chemical nature, and in structure. The most important result thus far has been the demonstration of the high value of manure, alfalfa, and pastured sweet clover in the rotations. Subsoil moisture studies have been conducted at the Union fruit farm in southeastern Nebraska, where apples are the important crop under investigation. These studies have shown the importance of deep subsoil moisture, for during drouth periods trees must subsist upon the moisture stored at great depths.

The question of what constitutes a properly balanced relationship between moisture and fertility has received some attention. Overstimulation and "burning" of crops is likely to occur wherever fertility is too great for the moisture supply. In measuring the water requirement of corn, T. A. Kiesselbach found that the addition of manure decreases the amount of water necessary to produce a given weight of plant tissue, but at the same time it also increases the growth and transpiration rate of crops. On well managed farms this knowledge is put into practice by maintaining a degree of soil fertility that is consistent with water supply, either rainfall or irrigation.

Rotation plots at the Scottsbluff substation.

During more recent years, Station men have attacked the question of how and when subsoil moisture that has been exhausted by deep-rooted crops like trees and alfalfa is restored. Studies of moisture to depths of 30 and 35 feet indicate clearly that restoration of this moisture is very slow and varies with the type of soil. On upland areas where there is runoff, the restoration rate has been found to be slower than in other locations. In certain types of soil investigated, particularly those with heavy subsoils, a calculation of the rate of restoration indicated that more than two centuries would be required to replenish the supply of stationary subsoil moisture. This is not true, however, of more favorably located and more permeable soils such as Marshall and others. These findings have much to do with farming practice as far as deep-rooted crops are concerned.

Early in the history of the Nebraska Station, agronomists and chemists predicted the eventual decline in the fertility of Nebraska soils. It is customary to hear the remark that Nebraska soils are rich and the statement is essentially true. Experimental work with fertilizers was begun in 1915 at Lincoln. Outlying fertility tests have been conducted since 1918. In certain western irrigated areas, crops have responded to applications of

phosphorus; in certain places in eastern Nebraska, to lime. On the whole, however, the chief loss has been in nitrogen, which is most readily replenished by manure and legumes. With the improvement of surveys, and the development of land-classification surveys, greater differences in types and phases of soils, in regard to fertility, are appearing, and thus the surveys become more reliable guides to proper land use.

With continued cultivation of sloping land comes danger of loss from erosion. Little experimental investigation has been done on erosion in Nebraska up to recent years. The lessons necessary to understand erosion have been learned in the older states. In 1923, the Agricultural Extension Service of the Nebraska College of Agriculture distributed a circular on "Soil Washing—the Cause and Method of Prevention," and since then a great deal of demonstration work has been done. In recent years the federal Soil Conservation Service has contributed much through project work. Projects may now be seen in several places in Nebraska.

Readings In Soils Science

One should read such popular books as P. B. Sears' "Deserts on the March" (University of Oklahoma Press, Norman, Okla., 1935) and Stuart Chase's "Rich Land, Poor Land" (McGraw-Hill, N. Y., 1936). Books of this sort present in popular style the problems of land use and their relationship to human welfare.

The Soil Conservation Service has sponsored many interesting and valuable bulletins and one could write to their regional headquarters at Salina, Kansas, or to Washington. Examples are "Little Waters" and "Conserving Corn Belt Soil" (Farmers' Bulletin 1795), and "To Hold This Soil" (U.S.D.A. Misc. Pub. 321). The United States Department of Agriculture Yearbook for 1938 is entirely devoted to soils and contains an excellent list of publications on the subject. Government publications are readily obtained from the Superintendent of Documents, Washington, D. C. For most of these a small charge is made, usually five or ten cents for bulletins. Stamps are not accepted in payment; one can obtain coupons, which are a convenience in ordering. Supplies of particular publications are sometimes available in other places, as county agents' offices, or from members of Congress.

The Nebraska College of Agriculture has several publications which may be obtained through the county agent or by writing to Lincoln. They are as follows: Extension Circulars 133, "Management of Nebraska Soils;" 118, "Brome Grass for Erosion Control;" 119, "Soil and Moisture Conservation in Nebraska;" and others. Ask for a list.

For information on the broader and more technical phases of soils science one should consult good textbooks such as Lyon and Buckman's "Nature and Properties of Soils" (Macmillan Co., N. Y., 1937), Weir's "Soil Science" (J. B. Lippincott Co., N. Y., 1936), Parkins and Whitaker's "Our Natural Resources and their Conservation" (Wiley and Sons, N. Y., 1936), and Ayres' "Soil Erosion and Its Control" (McGraw-Hill, 1936). (For irrigation see the section on Agricultural Engineering.)

County soil maps are useful to those with some knowledge of soil types; they may be obtained from the Division of Conservation and Survey, University of Nebraska, Lincoln. Other publications on Nebraska's natural resources may be obtained from this Division.

Crops and Crop Diseases

AT THE University of Nebraska a "state farm," as it was commonly called, was set apart from state-owned land in 1872 and soon disposed of, to be replaced by the new "state farm"—now the site of the College of Agriculture. Was it to be a farm—a model one—or to be a place for searching out "new agricultural truth"? Professor Samuel R. Thompson, then in charge, suggested that the model farm might have greater possibilities as a means of impressing the public, but the latter would be of more real service.

He conducted the first experiments—some tests on sugar beets. The purposes of the land-grant colleges were thus shaping toward scientific agricultural investigation, in addition to teaching.

As early as 1882, corn from six states was tested and two experiments were made of crossing corn grown in a distant locality with that of the common field corn grown in the state for several years. This was probably the earliest corn-breeding experiment conducted in the state.

The first decade and a half of crops work in various states, following the establishment of the stations in the late 1880's, were devoted almost entirely to the testing of a large number of kinds and varieties of crops in an effort to learn which were most productive and valuable in the various regions. This was especially true in recently settled states like Nebraska. Settlers brought crop seeds from their former homes. The Nebraska Station tested hundreds of varieties in comparison with each other, and introduced many from distant places. Crops such as chicory and tobacco were tried; details about their culture and yields may be found in the Station records.

Although some attention was given earlier to crop improvement by breeding, this work came into full swing after 1906, when, through the provisions of the Adams Act, the work of the experiment stations was enlarged. R. A. Emerson, horticulturist in the Nebraska Station (1899-1914), was one of the earliest of American plant scientists to demonstrate Mendelian principles in crop breeding.

The following years, especially the 1920's, also saw the introduction of many plants from other parts of the world, for the facilities of the stations and the U. S. Department of Agriculture were being increased. Sudan grass, soybeans, wild potatoes, Chinese elms, alfalfas, wheats, and other crops were searched out and brought home, to be tested first and perhaps later distributed.

In the past three decades plant breeding has become more complex and technical. Not only selection for the elimination of undesirable traits is

practiced, but hybridization is used, along with selection, to combine certain desirable characteristics of two or more strains or varieties in a new one. Inbreeding of open-pollinated crops, followed by hybridization, is used to eliminate weaknesses, as in the production of hybrid corn. Elaborate, precisely controlled equipment and large numbers of plants are used in testing the new selections and "crosses." Increased yields, superior quality, and resistance to disease and drouth in numerous cases now give promise of further excellent results. The search for better wheat, better corn, better potatoes will continue, even though the better adapted crops and crop varieties, in the more general sense, were long ago discovered.

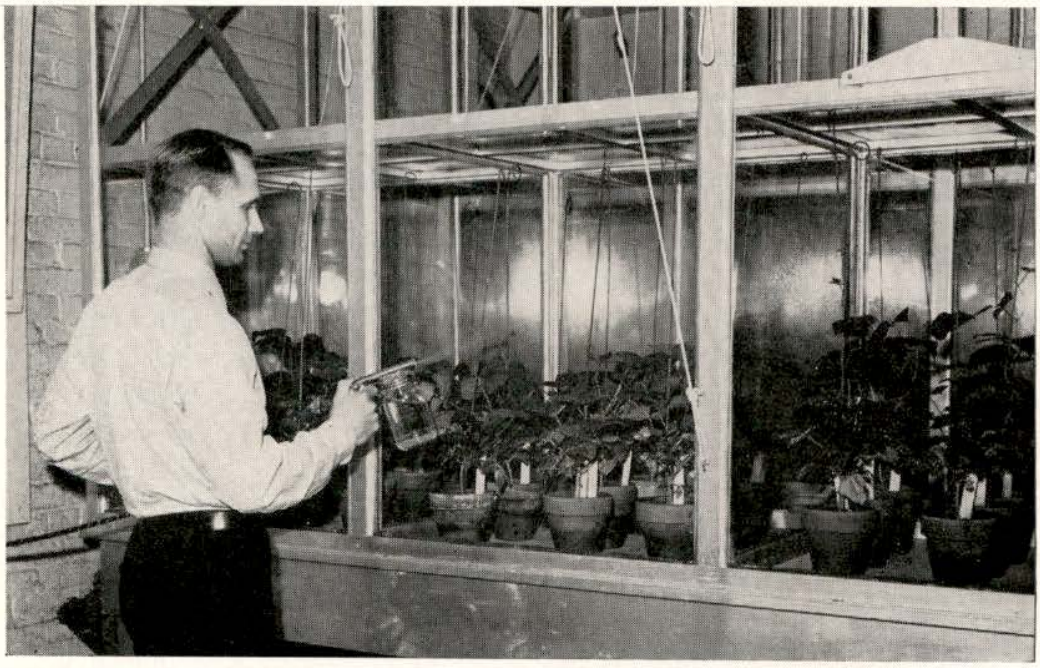
We may illustrate by pointing out that today only a few varieties or types of wheat, alfalfa, corn, and potatoes are grown extensively in Nebraska. Some confusion might arise from the use of the terms *type* and *variety*; a certain wheat, for example, may be the result of selection from another wheat; it may have resulted from a cross of two types; among its ancestors were perhaps several wheats introduced from Russia at various times. The general type may remain, and does for instance with Turkey winter wheat, but in some characteristics the new wheats are different. A highly desirable thing at present would be to breed into a new wheat the character of resistance to black stem rust. This is being attempted. The most recently developed and distributed variety of winter wheat, Nebred, is highly resistant to the races of bunt that are found in Nebraska.

In 1888, 26 varieties of legumes, 20 kinds of corn, 12 of sweet corn, 19 of oats, 126 of potatoes, and 61 grasses (including both native and cultivated) were being tested at the Nebraska Station. Such investigations were common in other states also during the period; for instance in the year 1904 almost 1,300 tests of 490 varieties of corn were conducted in the United States.

The study of plant diseases has been an important part of the work with crops in the Nebraska Station. C. E. Bessey, the first director, was one of the earliest American botanists to see the importance of this subject. In the late 1870's, T. J. Burrill of Illinois had discovered that bacteria cause plant diseases. As a result, studies of plant diseases were given an impetus. Very early the Station botanists at Nebraska began a collection of fungi injurious to the crops of the state and the plant pathologists of the Station have continued this work up to the present. A great deal of work on the rusts has been done— especially the rusts of wheat and other small grain. The major lines of work have included effects of environmental factors upon virus diseases, especially the virus diseases of potatoes. The Nebraska Station has developed extensive equipment for the control of temperature and other environmental factors in the study of plant diseases. This equipment has been especially valuable in determining the conditions for infection with many diseases and the effect of temperature on the development of disease symptoms. The intensive study of frost resistance and winter hardiness in plants has been made possible by the use of the

temperature-control equipment, which also provides a means of testing new varieties of plants under controlled conditions.

With every one of the major crops in Nebraska there have been diseases to fight. With wheat the chief problems have been rust and smut control. For potatoes, the principal diseases are spindle tuber, Fusarium wilts, tuber rots, and scab. Cherry leaf spot, fire blight, wilts, and numerous other diseases of fruit and forest trees have been studied, and sprays and other control measures have been recommended. Bacterial wilt, a comparatively new disease, has been a cause of serious loss of alfalfa in the state, and the Station has made some fundamental studies.



Greenhouse facilities are used in plant breeding and in the study of plant diseases.

An interesting phase of the early work with crops, which has been continued to the present, has been the testing of widely advertised "new" crops. In 1889 Jared Smith, who reported the earliest field experiments and observations for the Nebraska station, pointed out that Hampshire or English Cow Grass was the same as common red clover; and in 1895 C. E. Bessey characterized "sacaline" as a rank fraud of no value as a forage plant. Even today the zeal for something new often results in unprofitable attempts to grow an unadapted or unsalable crop.

Various associations of farmers and crop-improvement specialists have done much to promote better crops and crop-growing practices. At the turn of the century an association of agricultural students was operating effectively. This was made up of students and former students of the University's agricultural school. Local associations and the farmers' institutes were doing much. The Nebraska Crop Growers' Association, the Horticultural Society, the Potato Improvement Association are some of

the organizations operating at present, along with the Extension Service of the College of Agriculture.

Crop improvement may be said to be well advanced, as compared with its status fifty years ago. The generally adapted types and varieties are well recognized. Each year, however, drouth threatens; diseases and pests are a constant menace; a new industrial development such as the combine may point to the desirability of a new and different type of crop. The crop-improvement specialists have many goals set for them.

Literature on Field Crops, Garden Crops, and Forestry

Since crops are plants, anyone interested in crops will probably be interested in the fundamentals of botany. Textbooks on elementary botany will supply the need here. A very good and practical book is Hughes and Henson's "Crop Production" (Macmillan Co., N. Y., 1930), which deals with field crops and problems related to their production. Robbins' "The Botany of Crop Plants" (P. Blakiston's Son and Co., Philadelphia, 1931) is a good reference book. Gardner, Bradford, and Hooker's "Fundamentals of Fruit Production" (McGraw-Hill, N. Y., 1922) is one of numerous good books on that subject. Jones and Rosa's "Truck Crop Plants" (McGraw-Hill, 1928) is worth while for anyone interested in truck crops. A good introduction to the subject of forestry is Pack and Gill's "Forest Facts for Schools" (Macmillan, 1931).

Bulletins and circulars published by the U. S. Department of Agriculture and the Agricultural Colleges are abundant. Lists may be obtained.

The following publications from the Nebraska College of Agriculture are suggested: Bul. 293, "Cultural Practices in Corn Production"; Bul. 305, "Effects of Age, Size, and Source of Seed on the Corn Crop"; Ext. Circ. 136, "Corn in Nebraska"; Annual Mimeographed Reports of the Cooperative Crop Tests (including hybrid corn and varieties of wheat, sorghums, barley, and oats); Bul. 310, "Trees, Shrubs, and Vines at the North Platte Substation"; Bul. 316, "Grain and Forage Sorghums in Nebraska"; Ext. Circ. 134, "Sweet Clover Management"; Ext. Circ. 135, "Field Bean Production"; Ext. Circ. 1211, "The Farm Vegetable Garden"; Ext. Circ. 1201, "Farm Potato Storage in Western Nebraska"; Ext. Circ. 1259, "Potato Disease Controlled by Seed Treatment"; Ext. Circ. 1263, "The Why, Where, and How of Orchard Planting"; Sta. Circ. 50, "Bindweed Eradication"; and Sta. Circ. 59, "Common Native Grasses of Nebraska." There are others. Ask for lists.

For schools with courses in which field crops and soils may be taught, inexpensive laboratory supplies, consisting of plant and soil material, are available from the Department of Agronomy, College of Agriculture, University of Nebraska at Lincoln. A catalog is available on request.

"Nebraska Weeds" (Bul. 101 of the Department of Agriculture and Inspection, State of Nebraska, State House, Lincoln), should be in every school library. It is obtainable on request. Excellent publications (but no longer in print) on the history of crops research in Nebraska are Research Bul. 20, "Corn Investigations"; Research Bul. 31, "Wheat Investigations"; and Research Bul. 36, "Alfalfa Investigations." These review research work in Nebraska up to the early 1920's.

A few of the U. S. Department of Agriculture publications (Farmers' Bulletin Series) are: 1744, "The What and How of Hybrid Corn"; 1236, "Corn and its Use as Food"; 1722, "Growing Alfalfa"; 1731, "Alfalfa Varieties in the United States"; 1645, "Sugar Beet Culture"; 1436, "Why Potatoes Run Out"; 1367, "Control of Potato-tuber Diseases," and 1405, "The Windbreak as a Farm Asset." There are many others.

Corn

THE COMING of settlers to Nebraska amounted really to an extension of the Corn Belt from Iowa westward across the state. Corn is important in Nebraska; about half of the cultivated acreage here is devoted to it. As corn moved westward, however, certain adjustments in type of plant were necessary. These came about as a result of knowledge and experiment on the part of crop specialists and farmers, aided by the ready adaptability of the crop itself. As we have noted, the state of Nebraska is so situated geographically as to include a wide variety of climatic and soil conditions.

So far as corn is concerned, the chief problems have been, first of all, finding the best-adapted types, second continual improvement through selection, third the study of cultural practices, and fourth (the most recent and perhaps the most valuable) the development of hybrids.

In 1903 the Station's agriculturist, T. L. Lyon, observed that "corn brought from outside the state does not yield so well as corn from seed raised within the state." In the course of years, the corn originally brought in by settlers had become adapted. At North Platte an excellent selection called Substation White was developed; for the most part, however, selection was carried on within the standard varieties, and experimental work was conducted to determine the plant and ear characters most suitable under the varying conditions. It was found that long, slender, dimple-dented ear types tended to be correlated with smaller vegetative size and earlier maturity of the plants; while the large, rough ears with deep, starchy kernels indicated large vegetative size and late maturity. It was learned that the adaptation of this crop could be greatly affected by selection for specific plant and ear characters. Thus corn came to be adapted within the state.

Extensive studies have been made of the adaptation of corn, in a given locality, when seed is imported from various distances and directions. These studies have shown that eastern-Nebraskan farmers may safely obtain seed in Iowa or Illinois if they keep to the same latitude, or slightly north to offset the more favorable rainfall of those states. Seed of open-pollinated varieties cannot be moved north and south more than the breadth of two or three counties with safety. Because of the changes in climate and altitude across Nebraska toward the west, the regions of adaptation do not extend so far east and west as they do in states farther east.

These studies of the adaptation of open-pollinated corn preceded the coming of hybrids. When the possibilities of hybrid corn became apparent in the early twenties, plant breeders began to turn their attention toward commercial development. Hybrids have their areas of limited adaptation, just as open-pollinated corn does, even though any certain hybrid may be maintained and seed produced from its component lines in an area outside the area where it does best.

At present no very well adapted hybrids are available for the non-irrigated land of central and western Nebraska, but in eastern Nebraska several are being widely used. These have been developed by experiment station work or by private corn breeders who apply the principles as established largely by the experiment stations.

Hybrids require not only technical plant-breeding skill but also patience and a great deal of time. An official state inspection and certification service is maintained to assure correct procedures and identity of seed stocks in the commercial production of a number of outstanding established hybrids.

The process of development consists first of inbreeding through several generations, accompanied by selection, for the purpose of establishing a number of self-fertilized lines which breed essentially true to type and are fairly free from unfavorable characters such as weakness of stalk, barrenness, excessive suckering, and others. The plants become smaller and less productive during the process, but after several generations some of these "inbred lines" are chosen for hybridization because of their valuable characteristics; these lines can be continued in spite of the rigorous inbreeding. They can be kept in individual isolated plots free from foreign pollen or they may be maintained in the neighborhood of other corn if the tassels and ear shoots continue to be protected by paper bags and the pollination is done by hand.

Some hybrid combinations of crosses of inbred lines will produce the highly valuable and productive hybrid seed, and it is the work of the corn breeder to find the combinations of inbred lines that will produce the best hybrids. Because the yields from inbreds are small the practice of "double crossing" is used for the commercial production of hybrid seed; that is, two "single crosses," each between two inbred lines, are crossed together. The yields in such a seed field are relatively high and thus provide an abundance of seed that may be used by farmers in commercial corn production. Many farmers obtain certified seed of the two single-cross parents from experiment stations or commercial seed producers and make the final cross in isolated fields by detasseling one parent, which then bears the commercial hybrid seed.

Some warnings are issued to farmers. Not all hybrids are possessed of superior productivity and vegetative characteristics and the vigor of a good hybrid ordinarily will be greatly reduced in the second generation. The Nebraska Experiment Station does not release for use hybrids that have not yielded at least 10 per cent better than standard open-pollinated varieties in carefully conducted tests over a two-year period, and they must be superior in other respects. The use of state-certified seed grown under the inspection of the official state agency assures purity and productivity. The four hybrids that are officially certified in Nebraska have averaged 18 per cent higher grain yield than the standard variety, Krug, during the last five years. Any farmer may obtain the seed stocks necessary for making the commercial hybrids that are certified in the state. The production of hybrid seed is fairly simple after the seed stocks have been developed.

Other work on corn has consisted largely of studies of cultural practices. Seedbed preparation, rate of planting, and cultivation have been under test for long periods at Lincoln and North Platte. Early-spring working of the ground has been found appreciably more productive than has late plowing. The early working of the ground controls weeds and thus conserves moisture. Listing, where the land contours will permit, has proved an excellent practice. Double listing (both fall and spring) has not proved advantageous, nor has fall plowing in the eastern part of the state.

Several rates of planting have been tested but the standard practices of three plants per hill or the equivalent in drilled corn have proved best for

Corn hybrids are tested in comparison with varieties on farms in various parts of the state.

the more favored conditions of eastern Nebraska. In seasons of moisture shortage or westward in the state a somewhat wider spacing is preferred, ranging from about 18 to 24 inches between plants in rows 40 to 42 inches apart. Experimentation has shown that considerable variation in evenness of stand is permissible without serious harm.

Some of the cultivation tests have yielded interesting results. For example, tests concerning frequency and depth of cultivation have led to the conclusion that the chief objective of cultivation is weed control, which prevents the wasteful depletion of moisture reserves. There is no need of stirring the soil deeper than is necessary to destroy the weeds. On the other hand the amount of root pruning that takes place in connection with careful standard tillage practices has not been found detrimental to the crop. Roots must be cut both closely and deeply before the corn yield is seriously reduced. Late tillage after corn is normally "laid by" has not proved advantageous.

As with other crops, the work with corn has proceeded from the selection and adaptation of varieties and types to the more advanced and more modern plant breeding techniques of the present. The study of cultural practices, while less complex and difficult, has nevertheless required years of work with hundreds of individual testing plots at the central station and at the substation at North Platte. Among the investigators at North Platte who have had leading parts in the work with corn are W. P. Snyder, W. W. Burr, W. M. Osborn, and L. L. Zook. The latter is in charge at present. At the central station, E. G. Montgomery was in charge in the early years. For the past quarter of a century, T. A. Kiesselbach has been in charge and has been aided at various times by J. A. Ratcliff, C. A. Helm, W. E. Lyness, and Arthur Anderson.

Winter Wheat

THE GREAT fields of hard red winter wheat that cover southern and western Nebraska and most of Kansas were unknown 50 years ago. Wheat was prominent among Nebraska crops in the early years of the State's history, but nearly all of it was low-producing spring wheat. In the reports of 1880 and 1882, and also in Station reports of the 80's and 90's, numerous failures or low yields with strange-named varieties are mentioned. It is not known with surety who first grew the hardy Turkey Red wheat in Nebraska which was to give rise to strains now grown so widely. The chances are that it was brought into the state by Mennonite immigrants who brought with them seeds from their native home in southern Russia. Mennonite immigrants camped at Lincoln in 1873 and some of them settled on farms in southeastern Nebraska.

The change from spring wheats to hard winter varieties is the first chapter in a story that covers over 40 years. The Station tested and distributed superior winter wheats in the early years of the new century and has subsequently embarked upon a breeding program—a search for a new wheat that will resist pests, diseases, and winter killing; that will produce well and stand up stiff and straight for combining; and which yields a high protein flour that will bake into a light loaf. The end and aim of wheat growing is the production of a fine nutritious loaf of bread.

Not many years ago Nebraska wheat fared less well in the markets than other wheats because it was believed that its protein content was low. An economic study showed that protein content is an important factor in the price of wheat. By tests it was shown that Nebraska can and does produce wheats of high protein content. Cereal chemists of the Station have devoted a great deal of attention to standards of baking quality. This work, along with other studies of the chemical nature of flour, has been of value to the milling industry and cereal science in general and indirectly has aided in setting up standards for the wheat breeder as well.

Wheat breeding is a major enterprise in itself, and one which, in Nebraska, had its beginnings in the testing of varieties and selection of the

most desirable ones. By 1902, 118 varieties had been tested. Selections from Turkey wheats have in many cases given higher yields than the originals. After several years' trial, some strains out of the many hundreds that had been tested proved to be of particular interest because they out-yielded the original Turkey Red.

One, known as Nebraska No. 60, not only yielded high but in 1917, when winterkilling destroyed 82 per cent of the Nebraska winter wheat acreage, it showed superiority in hardiness.

Nebraska No. 60 was distributed to farmers in 1918 and by 1933, 55 per cent of the winter wheat acreage of the state was of this variety. Of the rest of the wheat acreage, Kanred made up 15 per cent and ordinary Turkey and other Crimean or Russian wheats made up the rest. Kanred

Winter wheats are tested in small field plots, as one part of the breeding work. Standing at right is Dr. T. A. Kiesselbach.

is a variety developed at the Kansas Experiment Station. In 1920 it was widely grown but has since declined in popularity because of its tendency to lodge.

The next major development in wheat breeding in Nebraska was the distribution in 1930 of Cheyenne, another pure strain, which had surpassed the old original Turkey by an even larger percentage than did Nebraska No. 60 in the station tests. Further, this variety is Hessian-fly tolerant; that is, it can endure attacks by local forms of this pest without severe loss in yield. It has excellent milling qualities, is resistant to cold, and the straw is strong. It is, however, susceptible to rust.

Another strain, Nebred (formerly called Nebraska 1063), was distributed to farmers in 1937. This strain has yielded well, is extremely smut

resistant, and somewhat more stem-rust tolerant than Cheyenne, but is susceptible to the Hessian fly.

Thus far in wheat breeding, various strains have been developed, each of which possesses some of the desirable characteristics, but not all. In recent years attempts at improvement through crossing have been begun and the aim is to develop a wheat which will possess *all* of the desirable characteristics. The work involves the making of large numbers of crosses and selecting the most desirable segregates from these, increasing the selections, and testing them for disease and insect resistance, hardiness, strength of straw, and milling and baking characteristics.

Of special importance has been the development of testing methods and equipment. Controlled hardiness tests are now possible by means of greenhouse equipment which makes possible the exposure of the young nursery wheats to almost any sort of artificial winter weather desired. Specially controlled nurseries are used for testing resistance to disease and Hessian-fly tolerance.

Agronomists at the Nebraska station and at the substation at North Platte have also studied cultural practices with winter wheat. Good soil-management practice requires early fall tillage to control weeds. Treatment of seed grain to control stinking smut is essential, although some of the newer wheats may prove to be so smut-resistant as to minimize the need for treatment. Surface drilling in 7-inch rows has proved the best method of seeding thus far, and four to six pecks per acre has proved satisfactory as a seeding rate. The most satisfactory planting date has been September 20 to October 1 at Lincoln, in years of little or no Hessian-fly infestation; with heavy fly infestation it is advisable to wait for the "fly-safe" date as announced by entomologists. The optimum seeding dates tend to become earlier northward and westward.

At present wheat breeding, through the cooperation of the U. S. Department of Agriculture and various state experiment stations, is more elaborate and more technical than ever in the past, for it is evident that the methods of the plant breeder accomplish results and it is evident also that the diseases and weaknesses of the wheat plant are formidable enemies. Rust epidemics are blown from the South; a severe and highly variable climate requires drouth resistance, hardiness, and lodge resistance. The Russian wheats, while productive, are far removed from the small peasant fields of their homeland; they must meet the heavier demands of present-day mechanized agriculture.

At the central Nebraska station T. A. Kiesselbach and Arthur Anderson have looked after the wheat-breeding for many years. C. A. Suneson has represented the U. S. Department of Agirculture part of this time, and more recently, K. S. Quisenberry. G. L. Peltier, pathologist, has conducted studies of rust epidemics and testing for hardiness. M. J. Blish and R. M. Sandstedt, chemists, have worked out a standard baking test and conducted other research in flour chemistry.

Alfalfa and Sweet Clover

IN GENERAL the programs in alfalfa investigations have followed those of the investigations of corn and wheat. The Nebraska Station workers are cooperating with men detailed from the U. S. Department of Agriculture in an elaborate breeding program. As with wheats, a great many strains have been introduced from Asia, Europe, and Africa. The modern testing methods are also applied to new alfalfas much as they are to wheat. Thus the young alfalfas are tested for resistance to bacterial wilt and cold. In addition they are tested in the fields for other characteristics such as yield.

Alfalfa was introduced into Nebraska early. Before the end of the century it was recognized as a valuable crop, and was grown on nearly a million and a half acres in the state during the 1920's.

Experimentation has shown that alfalfa is best seeded by drilling not over an inch deep. The use of a small-grain nurse crop with spring seeding is fairly successful, especially in the eastern counties. When seedbed conditions are favorable, early fall seeding, alone, is most commonly recommended in eastern Nebraska.

Alfalfa is harvested in the one-tenth to half bloom stage, because leaves, green color, and sweetness are retained to the greatest degree at this stage. A combination of partial curing in the swath followed by windrow-curing has proved good practice. Stacking or storage in a hay mow should be completed as soon as possible after curing to avoid needless loss of leaves and spoilage by rain. These practices have been tested experimentally.

Many strains of alfalfa are susceptible to a bacterial wilt disease which causes premature loss of stands. The disease is probably spread by water and by the cutting bar of the mowing machine. Studies of both bacterial wilt and winterkilling indicate that the best method of control is to develop resistant strains of alfalfa.

As part of a nationwide effort to improve alfalfa, seeds have been introduced by the U. S. Department of Agriculture from various foreign countries. From these and from locally grown alfalfas, several wilt-resistant varieties have been secured or developed. One strain, now known as Hardistan, was found growing on the Arnold Brothers' farm near Cozad, Nebraska. Seed from this field was obtained and increased, and in 1929 was distributed. Hardistan has proved to be remarkably hardy and wilt-resistant.

Grimm, Cossack, Ladak, and northern-grown Common alfalfas are the most suitable varieties now available for upland conditions, although on eastern-Nebraska uplands bacterial wilt is often severe and these varieties may live only three or four years. Hardistan and Turkistan, because of their resistance to bacterial wilt, are particularly valuable in the sub-irrigated valleys and areas under surface irrigation. In the large-scale breeding program, cooperative between several state stations and the U. S.

Department of Agriculture, promising strains are tested throughout the country wherever it is thought that they may be adapted. Alfalfa seedlings started in the winter at Bard, California, are transplanted the following spring in isolated plots in western Nebraska for seed production. Considerable amounts of seed have been obtained the same year, thus aiding the breeding program. Breeding has as its objective the development not only of a hay type but of a pasture type.

Other leguminous crops include sweet clover, other clovers, and the soybean. The part that sweet clover is to play in the rehabilitation of Ne-

Alfalfa with creeping root is shown at right. This type is being developed as a pasture plant. At left is a hay type. The creeping-rooted type was brought as cuttings from a goat pasture in northern Turkey.

braska pastures and hay lands and in the nitrification of Nebraska soils is undoubtedly a large one. Since 1920, the acreage of sweet clover has increased from less than 50,000 to over a million acres. In 1935, a program of sweet-clover improvement was begun at the Nebraska Station, in cooperation with the United States Department of Agriculture. Work is now being undertaken to improve sweet clover through selection and breeding, and to obtain varieties suitable for hay and pasture.

At the Nebraska station T. A. Kiesselbach has conducted a large part of the agronomic studies on alfalfa and G. L. Peltier was in charge of the major investigations of the bacterial wilt disease and resistance to cold.

In the program at present H. M. Tysdal represents the U. S. Department of Agriculture in the studies of alfalfa and Samuel Garver in studies of sweet clover.

Spring Grains, Sorghums, and Other Crops

A WIDE VARIETY of crops are grown in Nebraska, and a wider variety were grown in the past. Farmers, industrialists, technical men and others are always on the lookout for new crops. Flax was an early successful crop in Nebraska but is grown very little now. Chicory was tried early in the century and is now almost unknown. Millet is grown in places, buckwheat in a few places. At times, Jerusalem artichokes have been advocated, and some farmers have tried hemp. Safflower, pyrethrum, and

Atlas (left) and Kansas Orange sorgo (right) growing in plots.

others have been tried. In recent years soybeans have been tested extensively. On all of these, information is available.

At present there is a strong trend toward increase of grain sorghum crops, especially in the south central part of the state, and toward an increase in forage sorghums throughout the entire state. All farmers are familiar with cane and Sudan grass, which are sorghums, and in the recent years of drouth a great deal has been heard about this group of plants. Atlas sorgo has obtained a wide popularity because of its ability to produce extraordinarily heavy yields of silage or fodder. Other varieties of both grain and forage sorghum (or sorgo) produce well and compare favorably with corn, especially in years of drouth. Western Blackhull kafir,

Pink kafir, Early Kalo, Sooner milo, and Day milo are successful grain sorghums. Varieties should be selected according to their regional adaptation, which has been determined. Early Sumac, Black Amber, Atlas, and Leoti Red are good sorgos. There is, however, an apparent possibility for improvement and consequently the Nebraska Experiment Station has embarked on a comprehensive breeding program designed to develop types adapted to the various parts of the state.

It became evident early in the history of the state that early varieties of oats were more profitable than late ones; thus the trend in adaptation of oats followed that of wheat and other small grains. The small grains, unlike the corn and sorghum plants, cannot endure the heat and drouth of the late summer.

A Nebraskan, Professor F. W. Taylor, is credited with bringing Kherson oats to the United States from Russia in 1897. The Kherson oats mature early, and like Turkey wheats are adapted to the Great Plains. In Nebraska oats are grown extensively in the northeastern sections and are commonly used as a nurse crop with alfalfa, red clover, or sweet clover.

Nebraska No. 21, a selection of Kherson oats, has yielded about five per cent better than the parent Kherson oats over a period of 14 years of testing. Newer strains are continually being tested and many, such as Brunker, Nebraska Burt 518, Columbia, Iogold, and Trojan, have yielded well in recent years.

Barley has been grown from early times in small quantities. The roughness of the awns or "beards" of the early varieties made it unpleasant to handle in harvesting and threshing and lowered the straw value. The introduction of superior new varieties which had been grown and tested by the Station caused, about 1927, an increase in the acreage of barley in all parts of the state. In 1932 the acreage was three times what it had been five years earlier. The new varieties, such as Comfort and Glabron, are smooth-awned and their yield is about 20 per cent greater as well. Continued testing has shown the superiority of four other varieties: Spartan, Trebi, Club Mariout, and Flynn. Spartan has a seven-year average yield that is 33 per cent higher than common six-row barley. Spartan and Glabron are both smooth-awned and are especially lodge-resistant.

In the western part of the state spring wheat is a crop of importance. Until 1925, most farmers raised mixed varieties, and durum wheats were popular. During the next two years, attempts were made to weed out the inferior varieties and to improve the uniformity and quality of yield. This has resulted in an increased growing of two varieties, Marquis and Ceres. Work at the Box Butte Experimental Farm has indicated that two relatively new rust-resistant varieties, Ceres and Thatcher, are the best spring wheats now available for that region. Of these, Thatcher, a Minnesota wheat, is more rust-resistant.

Cultural studies with small grains conducted during many years have shown the necessity of seed treatment for the control of smuts. These

treatments have been proved effective by many experiment stations and the U. S. Department of Agriculture, and may be regarded as standardized. Broadcast oats have produced slightly less than drilled oats at the station at Lincoln and a wide range of planting rates for oats and barley—from 6 to 12 or 16 pecks per acre—have all produced about the same. In time-of-planting tests spring wheat, oats, and barley proved best when planted early.

Sugar Beets

INTEREST in beet-sugar studies in the University of Nebraska dates from about 1872, when an analysis of sugar beets raised for stock feeding on the University farm showed that beets contained over 15 per cent sugar. Sixteen years later, people in and around Grand Island made a systematic attempt to demonstrate that beets could be raised which were sufficiently rich in sugar to warrant the establishment of a sugar plant there. The new industry was further favored by the McKinley Act of 1890, which provided a cash premium to sugar producers in the United States. This act was repealed later and a tariff substituted. For a while the state of Nebraska provided a bounty of a cent a pound on all sugar produced in the state.

In Nebraska, the work of the Station chemist, H. H. Nicholson, did much to aid the development of the sugar beet industry. He not only made analyses but conducted experiments in cooperation with farmers and at a substation at Ames to determine the best varieties to grow and the best ways of cultivation. Factories were established at once at Grand Island and Norfolk. At present sugar beet production is carried on only in the irrigated areas. Over 80,000 acres of sugar beets are grown annually in the state, and the production is over a million tons. The by-products—beet pulp, molasses, and tops—are used extensively in the feeding of livestock, especially lambs.

It was early learned that sugar beets are one of the most expensive, but under the proper conditions one of the most profitable, farm crops to grow. They occupy an important place in the rotation experiments at the Scottsbluff Substation.

Twenty-five years' records show that sugar beets grown in rotation including manure and alfalfa average 18.7 tons per acre while in untreated rotations the yield has been 10.1 tons with a gradual decline. Manure with no alfalfa has resulted in an average yield of 17.3 tons; and alfalfa in the rotation, but no manure, an average yield of 15.2 tons of beets. Pastured sweet clover in the rotation has increased yields of beets 7.0 tons per acre as an 18-year average. Tests to determine the effect of phosphate fertilizer in these rotations were begun in 1937.

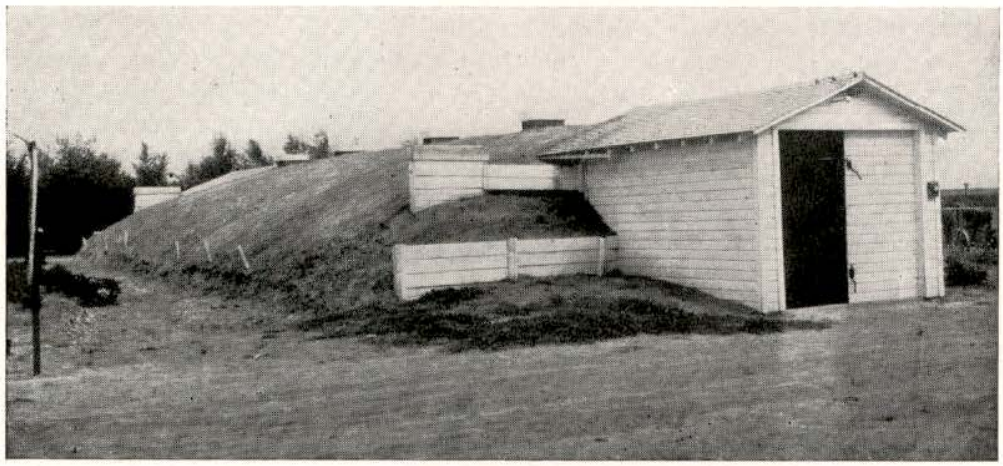
At present the Nebraska Station participates only to a small extent in studies of sugar beets, but in the 1890's, when the industry was first becoming established in America, the Station made important contributions.

At present the U. S. D. A. is carrying on research at the Scottsbluff Substation. Processing companies have carried on important studies of cultural methods and fertilizers. In all important phases the industry has had the aid of scientific investigation.

Potatoes

TODAY the only varieties of potatoes of commercial importance grown in Nebraska are the Triumph, Irish Cobbler, and Early Ohio. In 1924, 10 varieties were included in comparative tests; and in 1887, 176 named sorts of potatoes were being tested. Yet with all of this elimination, the ideal variety for the state has not yet been found, and the state workers are cooperating with the U. S. Department of Agriculture and with other state institutions in the production and testing of seedlings. In this work, control of temperature and day length by means of greenhouse facilities enables the workers to obtain climatic conditions of various kinds and to vary other factors in order to note the influence of each separate factor.

Selection and tuber-index propagation—that is, planting one section of a tuber in a greenhouse as a test before the remainder is planted in



A western-Nebraska potato cellar, Box Butte Experiment Farm.

the seed-increase plot—have greatly standardized the Triumph (the most widely grown variety in western Nebraska) until now we have early, midseason, and late strains that are practically free from virus diseases.

Even in the superior lots, however, degeneration or "running out" was encountered in the early 1920's, when the certified seed industry was becoming established. Seed lots grown under irrigation seemed to degenerate more rapidly than those from dry land, and for many years the phenomenon of "running out" was believed to be associated with irrigation. H. O. Werner's investigations, however, eventually revealed that "running out" was caused by a transmissible, tuber-borne virus disease known as "spindle

tuber" and that disease-free stocks produced in isolated, thoroughly rogued plots could be maintained indefinitely without deterioration.

Investigations were made on tuber-seed value as affected by time and depth of planting, use of mulches and irrigation water, premature cutting of the vines, and early and late harvesting. These showed that the late-planted or early-harvested lots were freer from disease, possibly because of the shortened period in the field. Spindle tuber spreads readily under the conditions provided by irrigation; but it has been demonstrated that the use of disease-free seed and the practice of crop rotation combine to produce healthy seed in the irrigated sections of the state.

With potatoes the disease factor is of great importance. In fact the certified-seed industry of western Nebraska is based on the fundamental fact that seed free of diseases can be produced. Early in the 1920's, when the industry was beginning to expand, extensive studies were made of the so-called degeneration diseases, the wilts and rots that affect potatoes, and control measures were provided. The most recently reported studies of the disease factor in potato production have been studies of the influence of the rotations at the Scottsbluff Substation on disease. In these studies R. W. Goss, Station pathologist, found that the longer rotations, with three years of alfalfa, were more conducive to the control of soil-borne diseases than were the shorter ones.

The present certified-seed-potato industry of western Nebraska is a direct result of the seed-potato investigations conducted by the Nebraska Experiment Station. Until 1924, certification was under the direct charge of Station workers, but has since been turned over to a cooperative association of growers, although technical supervision by the Station is still exercised. Certified Nebraska Triumphs are now used in many southern states as a standard by which to judge seed-potato value.

One of the large sources of loss to potato growers has been that from injury at harvest by machinery and handling. Extensive surveys and experimental trials have shown the way toward the elimination of such losses. Not only has machinery of better design been developed, but harvesting methods have been improved.

The following statements briefly summarize the cultural methods that have been worked out through experiment.

1. In eastern and central Nebraska, potatoes should be planted in April and grown as an early crop.
2. Late May or early June plantings produce the largest yields in western Nebraska. Commercial plantings are now delayed until June 15 to 25 in order to reduce losses from disease and insect damage and to increase tonnage of high-grade potatoes.
3. Restrict cultivation to weed control.
4. Where moisture conservation rather than drainage is the major problem, ridging the potato row in unirrigated fields is impractical.
5. As shown by tests at the Box Butte Experimental Farm, the chances for a crop in the western unirrigated regions are slight if less than

three feet of soil contains stored moisture at planting time. A good crop is assured without summer rainfall if at that time the upper four or five feet of soil is filled to field carrying capacity with moisture.

6. Summer fallow is an effective means of storing soil moisture. Reasonably good crops follow corn or beans, but in drouth years potatoes are a failure after small grain which more completely exhausts the soil moisture during the previous year.
7. The storage of potatoes in a damp cellar for a few days after digging materially decreases losses from wounds made in harvesting. Seed pieces likewise should be stored in a damp cellar during the time intervening between cutting and planting.

Orchard and Forest Trees

AS SOON as a new land is settled, the people take an interest in the kinds of trees and fruits it will produce. In 1891, C. E. Bessey reported that "There are known to occur in the state 127 species of native trees and shrubs. The most important trees which are found in all parts of the state are the cottonwood, white elm, hackberry, box elder, green ash, and red ash. In the northwestern part of the state the western yellow pine, called also 'Bull pine', is the important tree. In eastern and southeastern parts of the state there are ten species of oak, five species of hickories, besides walnut, butternut, silver maple, wild cherry, honey locust, Kentucky coffee tree, etc."

From this it will be seen that the eastern part of the state marks the western limits of the deciduous forest of the northeastern United States. Likewise, the western yellow pine marks the eastern limits of the coniferous forests of the Rockies. Thus it is clear that a wide variety of trees may be grown in Nebraska, but tree culture, because of the climate, is difficult. It is, however, possible to have trees for windbreaks, fruits and ornamental purposes. Success depends chiefly upon the selection of species that are best adapted, upon finding good locations, and upon providing proper care.

The early printed proceedings of the State Board of Agriculture and the Nebraska Horticultural Society contain numerous reports of test orchards and gardens over the state. These together with discussions in the newspapers and magazines supplied a background for experimental studies in tree culture.

When the University farm was acquired there was a four-acre apple orchard on it. In 1895, 370 varieties of tree fruits were planted on another four-acre plot. Three years later ten acres were planted where the present orchard stands.

In 1918 forty acres were planted on the 80-acre University Fruit Farm at Union. This farm is on loess soil and is forty miles east of Lincoln.

In contrast to the earlier planting, the last one contained only twelve varieties of apples. In the course of years, the unsuccessful sorts had been eliminated. In the course of time, too, small home orchards, planted chiefly in the early eighties, have come into bearing and have declined; and orchards as commercial enterprises on a large scale have been planted extensively in southeastern Nebraska, chiefly on loess hill ground in the tier of counties along the Missouri river.

Recently terraced hillside on the Fruit Farm at Union. Plantings will be made in the spring of 1939.

The services of research workers and orchard specialists were in demand early. In 1891, fire blight, a bacterial disease, was studied, and some information about the nature of the disease was obtained. Station workers in 1905 reported that cedar rust could be controlled by Bordeaux mixture but the recommendation is no longer made; destruction of the cedars and use of resistant varieties of apples are recommended for the control of this trouble. Some studies were made in 1916 of Illinois blister canker, a disease that is difficult to control and which has caused extensive losses.

Spraying tests to control insects, under the direction of F. W. Card, were first reported in 1899—the work being directed toward producing worm-free apples. In 1900 some trees were caged in order to determine more definitely the effect of sprays in the control of this pest. In late years insect control studies have involved the use of new insecticides, including egg-killing sprays, and their relation to the spray residue problem.

About 1906 commercial spraying was begun and for the next six or eight years an extensive demonstration program directed by R. A. Emerson and J. R. Cooper, the Station horticulturists, was conducted in eastern Nebraska. Various sprays, nozzles, etc., were tested and the foundation

was laid for the present universal use of sprays as a means of producing salable fruits.

Soil care for orchards was early recognized as a problem in this territory, and in 1894 some tests of winter care were made. More extensive tests showed a few years later that fall-growing crops, as compared with clean cultivation, made late-growing fruit trees more hardy.

With the establishment of the orchard at Union in 1918, an opportunity presented itself to follow out further the orchard culture program. Blocks running crosswise of the varieties and blocks with different spacings have been under observation for the past fifteen years. Little outward difference can be noted except that clean-cultivated areas had to be abandoned on account of soil erosion. Recent soil moisture studies by C. C. Wiggans have revealed a much greater use of reserve moisture in the areas where trees are closely spaced. Apparently trees begin to utilize subsoil water whenever surface moisture is not present and their life span depends upon the time necessary to use all available subsoil water. This in turn depends upon soil texture and depth. Present recommendations are for wide spacing and the use of terraces or contour planting if the orchard is to reach old age—that is, beyond 35 to 40 years—and remain productive.

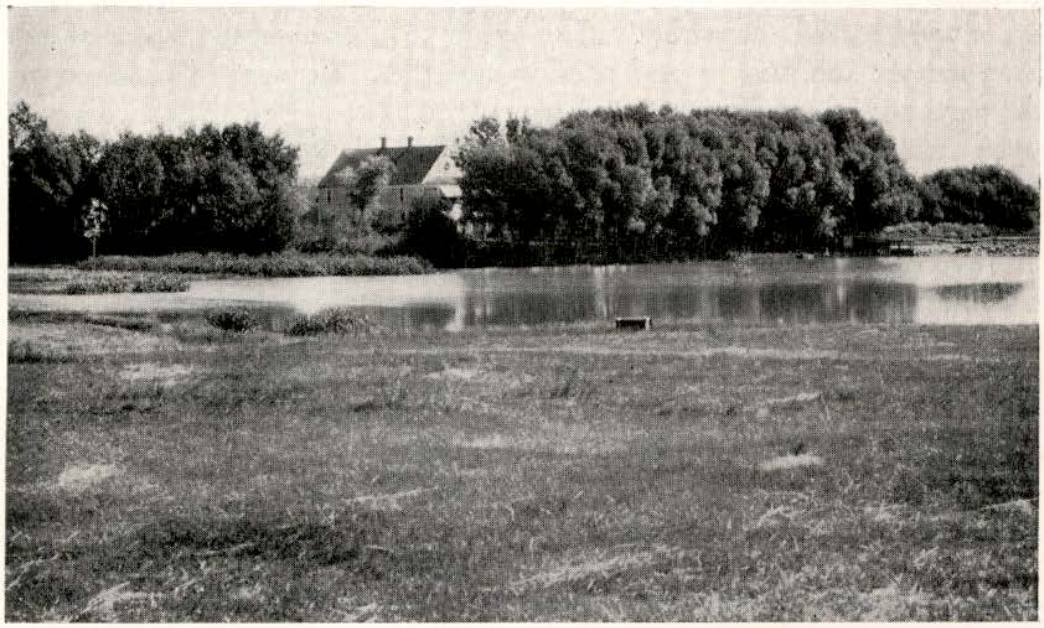
Involved in any program of fruit production is the question of winter-hardiness. Hardiness observations became one of the early projects. As early as 1900 it was determined that peaches, sweet cherries, apricots, and Japanese plums were not well adapted to Nebraska conditions either because of bud killing or even loss of the tree. Much winterkilling of raspberries and apples led to a search for hardier sorts and even to an interplanting of various fruits in the cottonwood grove at the east end of the farm. R. F. Howard conducted a study of this subject and learned that apple tree roots die more readily in dry soil than in wet and also that roots from the cion are more cold resistant than roots from the ordinary French crab seedling used for stock purposes.

To prune or not to prune has always been a debatable subject among fruit growers. It was soon learned, however, that heavy root pruning at transplanting time was detrimental to tree survival. In 1898 some attention was given to the consideration of low and high heading of trees, the final conclusion being that low-headed trees are preferable.

In 1932 a study of apple-tree roots was begun. The entire root systems of a number of transplanted trees were excavated after one, two, and three years in the orchard in an effort to learn how extensive the underground growth becomes under various types of soil care and with various degrees of competition with other crops. W. W. Yocum, who conducted this study, learned that competition with corn the first year had a tendency to restrict the spread and increase the depth of penetration, while a straw mulch produced a much shallower but very finely divided root system. These findings show that trees will not seek moisture from deep levels and dry out the soil to great depths if moisture at the surface is available or is conserved for their use by a mulch.

The abundance of wild grapes in the state showed early that grapes have a place in Nebraska and in fact grapes have been included in practically all experimental plantings. A comparison of "short" or spur pruning with "long" or cane pruning has shown that the latter type may produce as much as 10 per cent more fruit. In a soil-care study begun in 1924 no effect from fertilizer (nitrogen) applications has been visible. A straw much, however, has been a great conservator of soil moisture—the mulched area being still well supplied with subsoil water. In comparison, the cultivated block has lost from one-third to one-half of all available water to a depth of 30 feet during the first fifteen years.

The settler gave a great deal of attention to groves and orchards—in fact millions upon millions of trees were planted in the early days of



Ranch home, showing the advantages of trees.

Nebraska history. The attention of experiment station men and botanists of the University was attracted early to the question of whether or not the Nebraska sand hills—so obviously unsuited to cultivation—could be forested. The discussion continued and eventually led to the establishment of the Nebraska National Forest at Halsey and the Niobrara Forest Reserve near Valentine, both under the federal Forest Service. The Bessey nursery at Halsey was named in honor of C. E. Bessey and it is from here that young pine trees are sent each year to thousands of farmers in accordance with the Clarke-McNary Act. Broad-leaf varieties that are distributed under the same Act are obtained from commercial nurseries.

The Nebraska Experiment Station has made some contributions in the field of forestry but forestry has never been a major field of endeavor. Cooperative forestry plantings supervised by the U. S. Forest Service were made in 1896. Several acres of catalpa, ash, black cherry, osage orange,

honey locust, etc., were planted with various spacings. All of these plantings have been taken out. Soil samples from some of the blocks before their removal revealed the fact that practically all available subsoil water had disappeared above a gravel and sand layer at approximately 30 feet. For the past several years these trees had made little or no growth because they had been forced to subsist on annual rainfall. This perhaps gives an inkling as to the reason so many farm groves have succumbed during the last two or three years and also explains why in other instances only the border rows survive. Possibly, too, it indicates that shelterbelt strips should not be too wide.

In a brief study of strain adaptation, seeds of various species such as walnut, black locust, etc., were obtained from localities ranging from Louisiana to Manitoba. Seedlings from northern-grown seed produced smaller yearly growth because they stopped growing early, but they always escaped the winter injury suffered by the southern seedlings. This brought out very forcibly the importance of seed supply source in any case involving hardiness and adaptation.

Because Nebraska was almost a treeless state the use of windbreaks was more or less universal. Early studies showed the value of such plantings in lessening the amount of water needed by crops planted north of the windbreaks. The windbreak is effective because it breaks the force of the wind. Beneficial effects are proportional to the height of the windbreak.

At the various outlying experimental substations numerous species have been tried in windbreak and ornamental plantings. An especially large number have been tried at North Platte. This work, on a variety of locations and soils, has aided in the development of principles of tree management for the Nebraska plains areas, where the desire for trees has been so keenly felt.

Native Hay and Pasture

THROUGHOUT the history of Nebraska, the increase and extension of settlement has at times resulted in the putting of land into uses for which it was not well adapted The periods of the Kincaiders and of the World War are examples of times when much land was put under cultivation which might better have been left as grazing land. Federal and state agencies are now formulating plans for the rehabilitation of native grasses in parts of the state, through protection from overgrazing, reseeding, and plant breeding. One may see such work in progress at the larger experiment stations and in the various demonstration areas of the Soil Conservation Service. It is not new work, and yet it has a promising future. The grasses are coming to be regarded as of utmost importance in soil and moisture conservation, in addition to being excellent livestock feed.

Early Station workers were interested in the native grasses. Bessey reported in 1900, after a visit to the western part of the state that "the

natural grassy covering of the high plains is one which yields perennially a large amount of very valuable forage. No portion of this fine natural pasturage should be disturbed by the plow. It is impossible for man to replace the natural pasturage with anything which will equal that which Nature has placed there."

As early as 1900, tests of 128 grasses and forage plants were conducted at the Station in cooperation with the U. S. Department of Agriculture. The object then was to determine the extent to which native and cultivated grasses could be incorporated into farming practices. One of the chief difficulties—then and now—is harvesting seeds and obtaining stands. Generally speaking, the native wild species cannot readily be domesticated. Some progress has been made with wheat grass, but as yet satisfactory man-

Native-grass hay meadow in the sandhills of Nebraska.

agement practices have not been worked out for nutritious species such as buffalo grass and blue grama. It is known that they will return naturally, but the time required is long. Some studies have been conducted on the years required for reestablishment of native species on abandoned areas in western Nebraska which show that 10 to 20 years are required for complete restoration of the perennial short species.

Studies near the Valentine substation have dealt with such legumes as red clover which are commonly introduced into the native meadows of the sandhill country and of the outwash plains area to the east. Where water is not more than three feet below the surface in March, clover will establish itself and make the hay and pasture more nutritious by the addition of protein.

In recent years, pasture improvement has been sponsored by the Extension Service of the College of Agriculture. The measures used are weed control and, in old pastures, the seeding of mixtures varying from

section to section but usually including some tame legumes and grasses, chiefly brome. Brome grass has proved hardy, well-adapted, and generally useful, and with a small addition of alfalfa, has proved highly successful.

Weeds

PEOPLE HAVE always known that weeds are costly. Numerous estimates of their cost have been made, and these vary widely. Investigations in various institutions have shown that the water requirement of corn, per unit of dry matter produced, is only a third of that of the common ragweed, half that of the sunflower and rosin weed, and about the same as that of the Russian thistle. Ragweed, wild oats, and pigweed use almost as much nitrogen as does wheat, and they use more phosphoric acid. These high requirements of weeds mean that not only are they a more costly crop than useful plants but they reduce yields of regular field crops through depletion of moisture and fertility.

Early station workers in Nebraska were weed-conscious, but their efforts were chiefly confined to weed surveys and warnings. According

A heavy infestation of field bindweed.

to the Annual Report for 1891, the sandbur, buffalo bur, sunflower, horseweed, ragweed, squirrel tail grass, cocklebur, and porcupine grass were the worst weeds in the state. The Canadian thistle had been reported in the state and the Russian thistle had begun to attract attention in the northern part. By 1893, the Russian thistle had spread so widely during those dry years that a great deal of alarm was felt. The following year a ten-page bulletin on the Russian thistle, with photographs and fine drawings, was published. Farmers were urged to destroy it in their fields, to clean up roadsides and railway embankments, and to cooperate in the control of the pest. Its rapid spread was attributed to railway transportation, since the trail of the weed closely followed the railroads. The abundance

of the weed set people to wondering if a use might not be found for it. In 1897, C. E. Bessey reported that " a good suggestion is made by one correspondent who sees a possible fuel in it." It was suggested that the dry weeds be chopped and pressed into semi-solid cakes to be burned. A few years later, the Russian thistle was reported to be of value as an early forage plant for sheep. Bessey wrote that "as long as the plants are small and soft the sheep eat them with great avidity. They are very nutritious and there is no reason that I can see why this plant should not soon be taken out of the list of thoroughly depraved plants." The Russian thistle is unable to compete with crops under favorable farming conditions, and with the return of moister conditions about 1900 it ceased to be regarded as a serious menace.

About this time the perennial field morning glory or bindweed (*Convolvulus arvensis*) began to attract attention. Bessey reported in 1900 that it was "becoming a pest of no mean ability." He was convinced that it would "make us a great deal of trouble," and recommended that the plant should be dug out wherever it appeared and the underground portions carefully raked out and burned. His prediction has been amply justified—so much so that in 1933 the state legislature passed a law authorizing the destruction of the pest along highways and providing means of enforcing bindweed eradication in fields neglected by the owners. Clean fallow for two seasons has usually proved effective against bindweed. Investigations reported in 1934 by Kiesselbach, Petersen, and Burr have shown that the number of cultivations per season may be reduced by permitting the shoots to grow a few days before each cultivation. The young plants draw on the food stored in their underground parts for a few days; thus they exhaust their reserve supplies.

Various chemicals have been tried, and of these sodium chlorate has proved effective and most practical. Use of it necessitates the abandonment of farming the field for at least a year, and is, in addition, expensive. Another effective means of fighting weeds that a farmer can employ is to make sure that he is sowing only weed-free seed, and that he is not spreading weeds by using infested manure, or straw for bedding or for feed that contains weed seeds.

While the Agricultural College has been concerned with practically every measure looking toward the control of weeds in the state, its activities have been confined largely to research work on eradication methods and to surveys. With the establishment in 1908 of a seed testing laboratory, organized cooperatively by the U. S. D. A. and the Nebraska Experiment Station, excellent facilities were made available for the detection of infested grains. Any farmer can have an analysis of seed made, and the weed seeds identified, by sending a sample to this laboratory which is now in the State House and under the direction of the State Department of Agriculture and Inspection.

Insects and Other Animal Pests

IN THE early history of Nebraska's statehood—the 1870's—plagues of grasshoppers descended on the settlers. The new land of the western great plains was not free from diseases, pests, and other similar sources of discouragement.

The second bulletin published by the Experiment Station was a report on some of the common injurious insects of the state, prepared by Conway McMillan, the first Station entomologist. It was a survey, an attempt to estimate the extent and character of the injurious insect populations of the state, and to inform people about them. As in other sciences, the frontiers of entomological knowledge have been pushed forward during the past fifty years.

One of the earliest entomological studies (1890) was concerned with insects injurious to trees planted under the provisions of the Timber Culture Act. Destruction by pests sometimes prevented settlers from "proving up" on their tree claims. As a result of the study certain sprays and other measures were recommended. In 1892 a study of the webworm caterpillar that attacks sugar beets resulted in the recommendation of deep plowing after harvest to destroy or bury the pupae deeply, and sprays were recommended for the larval stage. These studies were conducted by Lawrence Bruner, who became Station entomologist in 1888 and served for a long period.

One of Bruner's experiments, though a failure, shows a method that is sometimes successful in controlling depredatory insects. On a trip to South America in 1897-98 he discovered a fungus that attacked the grass-

Cornfield stripped by grasshoppers—Dawson County, July, 1931.

hoppers t[illegible]re and brought a culture of it back to the United States, but in experiments here it failed to work.

In 1901 he suggested in a Station bulletin that disking fields to a depth of two inches in early spring would turn up the grasshopper egg capsules, exposing them to wind, sun, and birds. "Above all," he wrote, "the protection of the wild birds of the country is absolutely necessary in order to keep down this as well as other insect pests." He also recommended the hopper dozer.

In most years the common native, nonmigratory grasshoppers in Nebraska do some damage, and when mild winters follow dry summers grasshopper population increases enormously. General outbreaks occurred over the Nebraska area in 1901 and 1902 and again in 1910 and 1911, while the long severe outbreak since 1931 is fresh in our minds. After general outbreaks subside, injuries may persist in favorable localities for several seasons—for example in the years 1917-21, injuries persisted and were severe in the North Platte Valley. In this region in 1922-23 experiments on poison baits were conducted.

As a result of these studies improved formulas for poisoned baits were developed, and the best time and method of applying them determined. White arsenic and sodium arsenite were found very effective in baits with a bran or alfalfa-meal base. Fresh baits were as much as 21 per cent more effective than stale and fermented baits. Amyl acetate, technical No. 1 grade, served as an attracting material. Poisons such as these were more effective against immature insects than against mature ones. In the drouth of 1936, farmers noticed that a great many birds were dying. A study revealed that the lack of water and the heat, and not the grasshopper bait, had caused the loss of bird life. These studies were conducted by Myron H. Swenk, who became associated with the Station in 1907 and later became director of the work in entomology. Recently some work on ground cornstalks and cobs as base materials, by Raymond Roberts, has shown that these materials can be used satisfactorily in poison bait.

The chinch bug staged outbreaks in Nebraska in 1871-74, 1883-87, 1892-1903, 1906-11, 1913-15, and 1920-26. In the 1892-1903 outbreak, Station entomologists tested the distribution of a fungous disease that attacked these insects, but again without success. The war on the chinch bug has continued. When small grains are harvested the bugs must migrate, and since they migrate on foot, they may be stopped and destroyed by traps. The creosote trap consists of a ditch around the infested field, with a line of creosote in it. The bugs will not cross the creosote line and are killed as they collect in the ditch. Thus adjacent fields of corn may be protected. Improved methods of fighting chinch bugs worked out by Nebraska entomologists were summarized in a publication by M. H. Swenk, issued in 1925.

Since 1867 when the Hessian fly first invaded the state there have been several cycles of destructive abundance of this pest. The last two involved the winter wheat crops of 1920-21 to 1926-27, and of 1928-29 and

1929-30, the worst years being 1922-23, 1923-24, and 1929-30. It has long been known that the Hessian fly can be largely controlled if sowing is delayed until, or slightly after, the adult flies of the main fall brood have emerged, so that there will be few or no flies to attack the young wheat. Since the time of emergence and egg-laying of the main fall brood varies from season to season, it is important to know for each particular season just when the date of safe sowing has arrived. This is learned only by surveys and observation stations. In the falls of 1923, 1924, 1925, and 1930, such field work was done and the dates of safe sowing for each county were given wide publicity. Largely as a result of delayed sowing, Hessian fly population rapidly declined. The threatened outbreak in the crop of 1930-31 was checked by two factors: the safe sowing in the fall of 1930 and the dry weather of that period.

Cutworms of many species have for many years taken a heavy toll of Nebraska crops. Especially in the lighter soils in northeastern Nebraska, the sandhill cutworm (*Euxoa detersa*) and other species have been persistently destructive for the past twenty years or more. A study was begun in 1916. The loss of young corn can be reduced by spreading poisoned bran-mash bait, but the problem of spreading was not solved until the development of a simple home-made spreader in 1930. The real solution of this problem must lie, however, in methods based on an intimate knowledge of the life histories and habits of the numerous species; for this reason, a key to the cutworms and armyworms that attack corn in this state, by D. B. Whelan, was published in 1935.

The most important apple pest in Nebraska is the codling moth. As early as the 1890's Station workers reported that spraying by the calendar of the eastern orchardists was ineffective, but it was not until 1928 that entomologists were able to make the study of codling moth a continuous project. In that year detailed life-history studies were started, and the tenth season of such studies was completed in 1937. No control substitute for spraying was found, but to be effective the spray must be applied at the right time. As many of the young worms as possible should be poisoned when they attempt to enter the fruit, or before, and the spray application should be made when the worms of the different broods are hatching and entering. For best results, the insecticide spray is applied four times in a season: one immediately after petal fall, a second (cover spray) two weeks later, a third two weeks later, and the fourth, which is designed to destroy the second brood, is normally applied early in July. The exact time of applying the sprays varies from season to season.

In 1908 the melon aphis was wreaking havoc in the melon and cucumber fields of the state. A search for a spray that would kill these aphids without injury to the tender cucurbit vines resulted in 1911 in recommendations of nicotine sprays which have been consistently, successfully, and widely used ever since. Investigations of the strawberry leaf-roller and botflies, also begun in 1908, were later reported upon.

In 1909 a study was begun of a pest that had appeared in newly sown winter wheat fields of southwestern Nebraska. Later it came to be known as the plains false wireworm. The study was carried on intermittently until 1923 when a final report was issued by M. H. Swenk, giving full measures of control. Also in 1909 Mr. Swenk began a study of the pine tipmoth in the Nebraska National Forest at Halsey and completed it in 1927. The life history of the insect was worked out and it was found that the pest could not be satisfactorily controlled simply by removal of the infested tips. The following year the western yellow pine sawfly, which was defoliating native pines in northwestern Nebraska, was studied. The life history of the pest was worked out, and parasites were discovered which brought it under control naturally within a year.

In the 1920's the Station entomologists made investigations of numerous insects, outstanding among which were the poultry lice and mites, potato flea-beetles, and corn root-worms. The latter pest was seriously destructive in several southwestern counties in 1929, and damage increased greatly in 1930. A systematic rotation of crops was demonstrated to check the outbreak and the infestation in 1931 was reduced to a very much lower level, with little serious loss. Important studies were also made on the control of stored-grain pests, or "weevil," which were published in 1922.

Such small mammals as pocket gophers, prairie dogs, ground squirrels, kangaroo rats, field and house rats and mice, and others cause not only annoyance but sometimes large losses. Of these, pocket gophers and prairie dogs have claimed the most attention in Nebraska. In a country that has long been occupied by the same animals, a balance between the vegetable feeders and the flesh-eaters eventually is attained and maintained. With the coming of white men, this balance in Nebraska was disturbed. Besides depleting the flesh-eaters, the pioneer converted much of the prairie into fields of grain and forage crops. With the decrease of their natural enemies and an increased food supply, life became easy and pleasant for the vegetable feeders.

Pocket gophers began increasing in Nebraska about 1900, and the increase became especially marked from 1908 on, largely because of increased alfalfa acreage. In 1912 the Station took up the problem and found a method of poisoning fresh vegetable baits and later devised a sifter-top pasteboard box which enabled the farmer to prepare the baits without handling the poison. In cooperation with the Extension Service, pocket-gopher eradication campaigns were put on in the various counties where these animals were most destructive.

In 1904, two members of the Station staff published a bulletin on destroying prairie dogs in which the merits of killing prairie dogs by gas and by poison are compared. A strychnin, potassium cyanide, molasses, and anise-oil poison over wheat, worked out at the Station four years earlier and modified by the Kansas Station, had proved to be effective but rather unpopular with farmers, who naturally dislike to leave violently poisonous materials about. Further experiments showed that fumigation

of prairie dog towns with various poison gases, of which carbon bisulphid or some other hydrocarbon is the killing agent, were successful. For very large towns, a combination of poisoning and gassing was recommended, and it was found that more than one application was necessary for complete success. The Station again took up the problem in 1912. Experiments were conducted to find more satisfactory methods of poisoning these animals, and the results were published by M. H. Swenk in 1915. These results, slightly modified by further experience, have enabled the cleaning out of the prairie dogs so that now they cause comparatively little loss. The methods employed have been the use of oats poisoned with a starchy coating containing strychnin, and fumigating with carbon bisulphid or calcium cyanide placed in the burrows.

Studies have been made on the economic relationships to agriculture of ground squirrels, kangaroo rats, jack-rabbits, cottontail rabbits, field mice, house rats and mice, moles, and other forms of mammalian life, as well as on the economic relationships of our valuable bird life.

Ring-necked Pheasants were imported into Nebraska for a number of years, beginning about 1915, and several years later had built up so large a population in central Nebraska that farmers were complaining seriously of their depredations. The question as to the food and economic status of this bird became quite controversial and in 1930 results of a study by M. H. Swenk were made public in a bulletin. It was found that where pheasants were permitted to build up large populations, they became harmful, but that moderate populations enabled the birds to do as much good as harm or even more. Investigations on other upland game birds, especially the Bob-white Quail, Prairie Chicken, and Sharp-tailed Grouse, have since been started, but not as yet published.

Readings in Entomology

For those interested in learning to name insects, H. E. Jacques' "How to Know Insects" (address Prof. Jacques, 709 North Main, Mt. Pleasant, Iowa) is interesting and inexpensive as well. A very good, standard handbook is "Fieldbook of Insects," by Frank E. Lutz (G. P. Putnam's Sons, N. Y., 1921). Other useful books include G. W. Herrick's "Manual of Injurious Insects" (Henry Holt and Co., N. Y., 1925) and E. Dwight Sanderson's "Insect Pests of Farm, Garden, and Orchard" (John Wiley and Son, N. Y., 1912).

Nebraska Extension Circulars maintained for the distribution of practical information include: No. 1106, "Control of Household Pests"; No. 1501, "Destroying Pocket Gophers"; No. 1502, "Directions for Poisoning Prairie Dogs"; No. 1506, "Corn Root Worms"; No. 1507, "Grasshopper Control"; No. 1508, "Cutworm Control," and others. There are a number of excellent Farmers' Bulletins published by the U.S.D.A. on insects, mammals, and birds.

Livestock Diseases and Sanitation

IN 1885, two years before the Hatch Act was passed, the Legislature of Nebraska had established an experiment station in the University for the study of animal diseases. It consisted of a few rooms used for laboratories and some houses and pens for pigs. Through investigations to be carried on here it was hoped that the enormous losses from animal diseases, especially hog cholera, could be stopped. Similar endeavor was in progress elsewhere. Federal quarantine regulations were becoming important. In 1884 transportation companies were prohibited from carrying diseased animals. Special chemical investigations of poisoning by sorghums and cornstalks were in progress at several experiment stations. In 1889 it was first shown that cattle ticks are involved in the spread of Texas cattle fever.

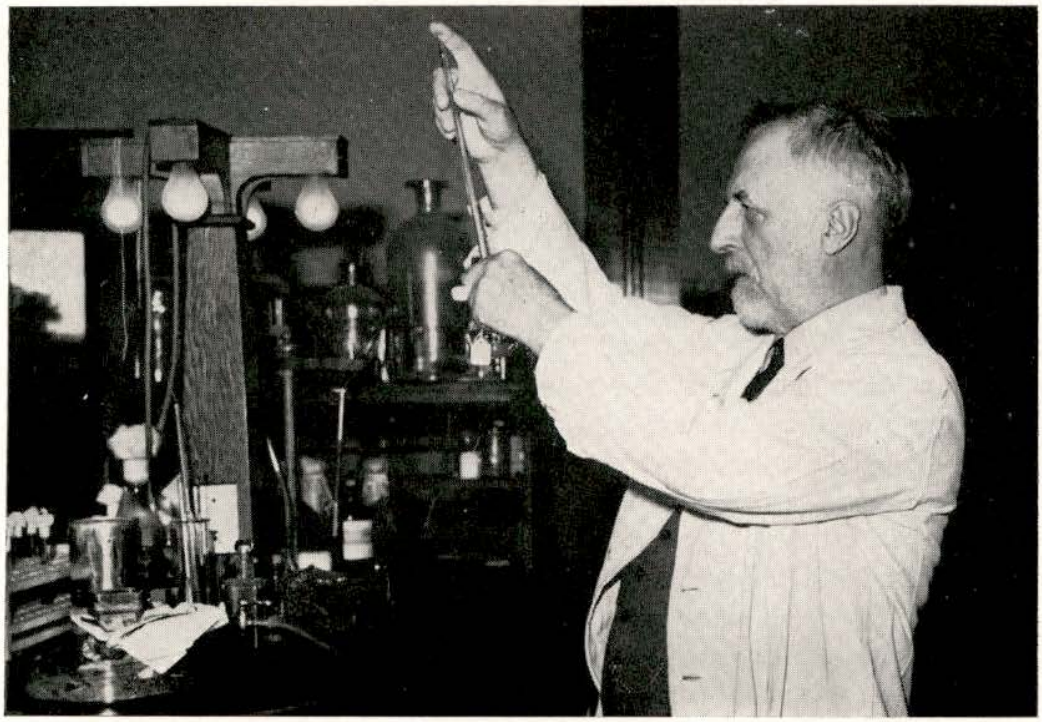
While early efforts at animal-disease control may seem now to have been wasteful and poorly directed it is none the less true that without wide observation and study, elementary though it may seem, and free dissemination of information, progress would have been impeded. In the early years at the Nebraska station no discoveries of importance were made. The work of Dr. F. S. Billings was extensive and he published large, controversial bulletins in which a present-day veterinarian would find much that is in error. On the other hand, Dr. Billings observed and reported conditions over a wide territory.

In 1893 A. T. Peters came to the station. Reports of station work show that he examined thousands of specimens and cases, cooperated with other stations in reporting and studying diseases, organized a reading club for the study of diseases of animals among stockmen, made some studies of poultry diseases, blackleg, cholera, "alkali disease" (now known to be selenium poisoning), milk fever, contagious abortion, tuberculosis of cattle, "swamp fever," so-called equisetum poisoning, and other diseases. In much of his work he cooperated with the Station chemists. His studies and observations impressed upon him the need for livestock sanitation. In 1899 he made the following remark:

"In almost every instance of contagious diseases we may attribute the whole trouble to sanitary conditions. Especially is this true in cases of hog cholera and tuberculosis. In one instance 95 per cent of a herd of about fifty cattle were affected with tuberculosis, one of which was so far affected as to be less than a mere skeleton, yet this animal was kept with the others. The sanitary conditions were about as bad as could be arranged. . . . We suggest that the term *cleanliness* is as desirable to stock as to the human race."

In this remark Dr. Peters anticipated the large steps that have since been made toward the control of diseases through the control of the environment in which they live.

The results of the years from the coming of Dr. Peters up to 1909, when Dr. J. H. Gain succeeded him, may be summarized as follows: Quarantine for the control of Texas cattle fever was carried out in co-operation with state officials, vaccination against blackleg was demonstrated, and a successful method for vaccination against hog cholera, discovered by investigators of the U. S. Department of Agriculture, was also tested and shown to be effective. During this period a Nebraska chemist, Samuel Avery, discovered that death among cattle from eating sorghum is due



The animal-pathology laboratory. Dr. L. Van Es is shown.

to prussic-acid poisoning. Of great importance then, as well as in late years, have been the warnings against quack medicines. In 1900, Dr. H. H. Nicholson, chemist for the Station, remarked in the annual report that "the field of veterinary medicine has been invaded by the unscrupulous mixers of drugs and potions. Hog cholera has made such serious inroads into the swine herds in this state that any plausible remedy or treatment has been eagerly tried." Dr. Nicholson supported his statement by analyses of some of the quack remedies then on the market.

With the coming of Dr. Gain, some work was done on tuberculosis of cattle, in addition to the other work carried on by his predecessor. The possibility of testing cattle to determine the extent of infection with tuberculosis was demonstrated and the earliest efforts were made toward

eradicating tuberculosis from the herds in the state. Nebraska became accredited as a tuberculosis-free state only recently.

In 1913, by legislative action, a plant for the manufacture of hog cholera serum was established under the direction of the experiment station. In 1918 Dr. L. Van Es, formerly dean of the veterinary school of the North Dakota Agricultural College, was put in charge of investigations of animal diseases at the Nebraska Experiment Station. During the earlier years Dr. H. M. Martin was associated with Dr. Van Es, and in more recent years Dr. J. F. Olney. At that time the laboratories and other facilities for investigation were enlarged and improved. Several major projects have been undertaken and completed since 1918, in addition to diagnosis of specimens and cases reported and sent in by farmers over the state.

Extensive work has been done on tuberculosis. This work may be said to be part of world-wide efforts to understand the nature of this important disease. In the early 1920's when tuberculosis of swine was apparently increasing at a rapid rate, an opportunity was offered for investigation. Materials from shipments of swine, mostly from northeastern Nebraska, were sent to the Station. With these materials, suspensions were made which were injected into guinea pigs and chickens. From a study of the effects on these laboratory animals, investigators could distinguish between tuberculous infections of bovine and of avian or fowl origin. It became evident in the investigations that hogs receive a large part of their tubercular infections from chickens.

Following the completion of this investigation, work was begun to discover the extent to which avian tuberculosis was to be found in other animals and in man. Hundreds of specimens of tuberculous materials of both human and animal origin were obtained from various sources. It was determined as a result that fowl tuberculosis can cause tuberculosis in cattle, and among the materials supplied by 227 cases of human tuberculosis no evidence was encountered which would indicate that the avian bacillus is a cause of tuberculous disease in man. Thus important contributions were made to the study of one of the most important diseases.

The Station has on several occasions worked on problems concerned with the poisoning of livestock as a result of consumption of poisonous plants or feeds. Early in the century, loco weed poisoning was studied and later on the cause of poisoning by sorghums was determined. Cornstalk poisoning has been studied and while the cause has not been determined, recommendations leading to the avoidance of serious losses can be made. In the late 1920's when serious losses among horses were occurring in western Nebraska, a thorough investigation of the pasture plants and some experimental feeding revealed that *Senecio Riddellii,* commonly known as ragwort or squaw weed, was the cause.

In more recent years the influence of environment of poultry—the yards, houses, feeders, and waterers—a factor in the cause and spread of diseases

has been studied. The problem was to measure the extent to which certain diseases can be controlled by sanitary measures. Two populations of poultry were used, one in a sanitary and the other in an unsanitary environment, and diseases were introduced into both. Nothing impractical was introduced into the sanitary environment and conditions too commonly found were allowed to prevail in the unsanitary environment. Feeding and management were the same in both cases as was also the cleaning. The diseases studied included Pullorum disease, blackhead of turkeys, tuberculosis, fowl cholera, coccidiosis, and fowl typhus. The results of this experiment cannot be summarized briefly, and it will suffice to say that diseases vary in the extent to which they may be controlled through sanitation. Pullorum, blackhead, and coccidiosis are profoundly affected by certain strict sanitary practices. All diseases vary in the extent to which they can be controlled in this manner.

More recently some work has been started on swine erysipelas, which has increased in the state during recent years, and upon a proposed method for immunization against hog cholera. In addition, a great deal of work not properly a part of the research activities is required to satisfy the requests for examination of specimens of animal diseases that have been sent in from various parts of the state.

Readings In Animal Diseases

Bulletins on particular diseases and some circulars on various diseases of particular kinds of livestock are available. Among the Nebraska publications are the following: Circulars 39, "Swine Sanitation"; 46, "White Scours of Calves"; and 56, "Prevention of Anthrax." A widely popular bulletin is No. 290, "Poultry Diseases: Their Nature and Control," which contains discussions of various poultry diseases and of the common parasites such as mites and lice. It contains the important results of the investigation of environment as related to poultry diseases. Bulletin 306, "The Evolution of a Sanitary Type of Chick Feeder," reports trials with chick feeders to determine methods of control of coccidiosis. Research Bulletin 84, "Swine Erysipelas," is a discussion of a disease that has recently been increasing in Nebraska.

Among the Farmer's bulletins of the U. S. D. A. are many that deal with livestock sanitation and diseases.

A general text that should be available in school libraries is L. Van Es's "The Principles of Animal Hygiene and Preventive Veterinary Medicine," (John Wiley and Sons, N. Y., 1932).

Production and Manufacture of Dairy Products

AT THE time the Experiment Station was established there was a growing interest in dairying, as is shown by the 213 per cent increase of dairy cattle in Nebraska between 1880 and 1890. With its wealth of natural pasture and its capacity for producing grains suitable for feed, the state was then, and is now, well suited for the development of the dairy industry. In these early years, the dairy produce that farmers marketed was chiefly butter. Farm facilities for separating cream from milk were inadequate, and in the 1890's skimming stations were developed throughout the eastern half of the state. These were stations equipped with large power separators which separated milk for farmers. In Nebraska a hundred and fifty such stations were established.

With the coming of the hand separator in the late 90's and following years, farmers were able to increase the quantities of butter and cream sold, and the skimming stations went out of business. The number of hand separators in use in Nebraska increased from 500 in 1897 to 30,690 in 1905. The development of this machine made possible the marketing of dairy products in regions far from market and thus extension of dairying became possible over most of Nebraska. Another factor which materially influenced the dairy industry was the discovery at the Wisconsin Experiment Station in 1890 of the Babcock test for the determination of the percentage of fat in milk and cream. This test was destined to become the basis for the development of the modern dairy industry. It permitted the rapid and accurate grading of milk at markets and discouraged adulteration and thinning practices. It showed the percentage of fat retained in buttermilk during the churning process and, by making practical the testing of milk of individual cows, promoted the development of better strains of dairy cattle.

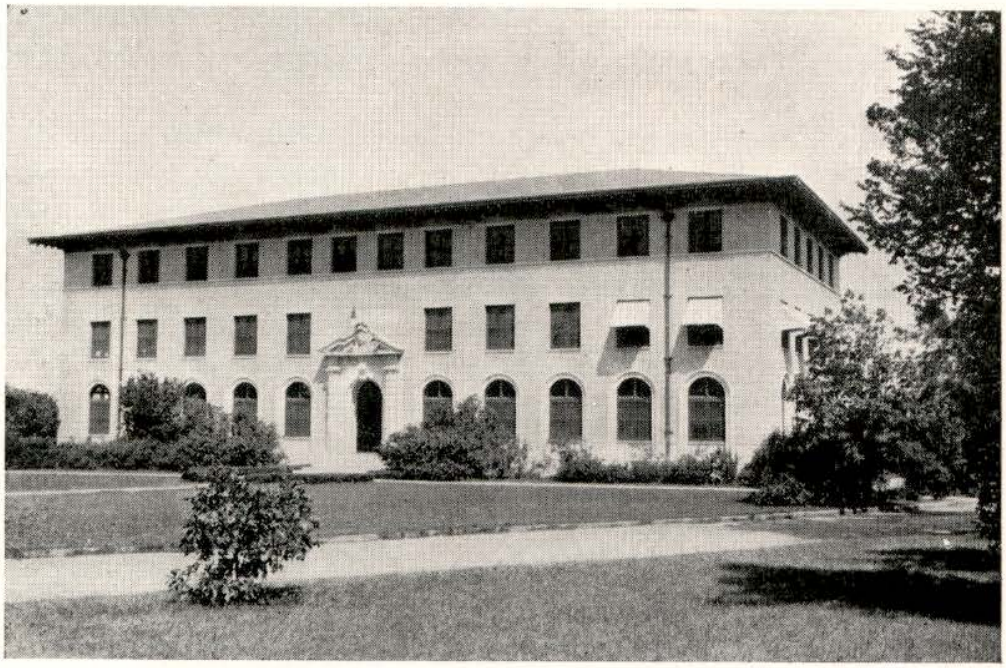
Two years before the establishment of the Experiment Station, the Nebraska State Dairymen's Association was organized. In the interests of dairying, this organization made plans in 1891 to appeal to the Board of Regents to establish a dairy school at the state university. This was done and in the course of the next decade, Nebraska advanced from twentieth to tenth place as a dairy state.

Experimental work in dairying at the Station was not attempted until the early 1890's, when a feeding experiment was carried on for four months. From these studies it was learned that the Babcock test was reliable, that cows vary widely in butterfat production, and that cottonseed meal im-

proved the ration; in addition the adverse effects on production as a result of severe changes in winter weather were measured. Similar studies had been conducted in a large number of other experiment stations. This work was developed during the next two years, but was interrupted in 1895 when all of the cattle belonging to the Station except one bull were sold and replaced with a herd of 10 grade Jersey cows.

Under the direction of A. L. Haecker, 1896-1911, the herd was managed with a view of improving the breeding stock. Feeding experiments of various types were devised and it was proved by experiment that calves would develop very satisfactorily on a skimmilk diet supplemented with ground feed. The hand separator had increased the quantity and quality of skimmilk on farms. Pasture tests showed that legumes improved production, that rye and sorghum afforded comparatively large amounts of pasturage, and that good pasture is of primary importance in dairy farming.

Cross-breeding experiments were attempted to determine the value of a dairy herd for the production of feeding steers, when beef sires were



The Dairy Industry Building at the Nebraska Agricultural College.

used. Studies during this and later years showed that the value of the individual animal can be shown only by her fat and milk production record. To build up efficient herds, information of this kind is essential.

In 1897, nine cows averaged 307 pounds of butterfat per year. By 1910 the herd of 40 cows was averaging 370 pounds of butterfat per year. In 1918 the average production of 43 cows was 401 pounds of butterfat, and in 1937, as a result of continued improvement, 49 cows averaged 567 pounds. In the years 1897 to 1936, an 87 per cent increase in butterfat

production and 118 per cent increase in milk production have been achieved through breeding and care.

Following the introduction of milking machines, A. L. Haecker and E. M. Little conducted investigations which showed that this equipment is impractical for the small herd.

Experiments during the years after the coming of J. H. Frandsen in 1911 as head of the work in dairying consisted mainly of a study of alfalfa hay and corn silage for milk production. As early as 1905 plans had been proposed for securing data concerning the average production of butterfat per cow by the farmers' herds in different sections of the state. The first cow-testing association was started in Douglas county in 1912 and in 1915 three cow-testing associations were cooperating with the Station. The work has grown and is now firmly established. Further attention was given to care of milk and cream on the farm; this has been a continuing problem, affected by market conditions and the development of new equipment.

During the sugar shortage in 1918, which was caused by the War, the Dairy Department conducted experiments with sugar substitutes in the manufacture of ice cream and found that corn sugar, while it cannot satisfactorily replace all of the cane sugar in ice cream, can replace 50 per cent of it in the mix.

New lines of work were developed following 1920, when H. P. Davis became chairman. In the field of dairy manufacturing, studies have been made which have contributed to improvements in manufactured products.

The utilization of skimmilk, which has always been burdensome to the milk plant and creamery, was one of the problems studied. Methods of making cottage cheese, Neufchatel, and similar cheeses were undertaken at this time and after suitable methods for making these products were developed at the Station these methods were recommended to commercial producers. Cottage cheese is now produced and consumed on a large scale, and soft-cheese manufacture has been developed to a point where a considerable quantity of this product is made and profitably marketed. Experimental work in the manufacture of ice cream and sherbets has been carried on to improve the methods used and to develop formulas and methods applicable to Nebraska conditions, where a law requiring a high percentage of butterfat necessitates some changes from formulas and methods used in other states where the fat requirement is lower. Recently studies of utilizing skimmilk surplus in the manufacture of frozen condensed skimmilk to be used in ice cream have been undertaken. Studies in manufacturing have for the most part been under the direction of E. L. Reichart. A method of testing ice cream for butterfat without elaborate equipment has been developed by L. K. Crowe; the test is a new, modified Babcock method, commonly called the Nebraska method. Work of this sort contributes toward more effective means of standardizing and improving the quality of dairy products.

During 1922 a biological laboratory (in which rats are used to study problems of nutrition) was established. This has made possible the study of the vitamin content of milk, milk products, and dairy feeds. Investigations by I. L. Hathaway include the vitamin content of milk as affected by breed and feed. Results have been obtained which show that the vitamin-A value of butter is far superior to that of many margarines and that artificial drying of alfalfa hay preserves its vitamin A and E content to a greater degree than field curing. The results also indicate that careful field curing produces satisfactory hay. The vitamin-A contents of A.I.V., molasses, and common silage were found to be different (ranking in the order named, with A.I.V. having the largest amount). All silages were found to be inferior to alfalfa hay in vitamin A. The milks produced by such feeds differed in the same way. Recently a study of the vitamin A in thirteen kinds of cheese has shown, among other conclusions, that cottage cheese is inferior to other kinds in this respect.

In 1932, P. A. Downs completed a seven-year survey of the farms from which milk was then purchased by the University. This study showed a high correlation between the quality of the milk and the cleanliness of the conditions under which it was produced. It was shown that farmers can, with inexpensive handling and cooling equipment, produce clean milk with low bacteria count. Work of this sort must continue, as it has continued since dairy science was made a part of the Experiment Station program. Milk and milk products are highly important as foods and require extreme care—more so than most food products. In cooperation with the engineering staff, dairy staff members have made studies of several types of cooling and storing equipment.

The study of growth in dairy cattle was begun in 1923 and is being continued. Through the accumulation of data on body measurements, weight, and age for different breeds of dairy animals it will be possible to set up breed standards for height and weight for the various ages and to determine where growth takes place. Considerable work has also been done by the University of Missouri, and the data obtained from the Missouri herd have proved to be correlated with the Nebraska data. This means that standards for weight, height, and chest girth at various ages for the various breeds are possible.

Through the separation and isolation of reactors to Bang's disease (contagious abortion), and through culling and sanitary measures in general, losses from Bang's disease have been reduced to a minimum, or to a place where little or no loss is suffered by the herd. In 1930, Station dairy specialists completed a study of the cost of the disease in the herd over a period of 32 years. During this period 1,226 calves were born, 180 lost, and the total financial loss was $159 per abortion.

Some work has been done in dairying at the North Platte station, in addition to the work at Lincoln. Except for protein concentrates such as cottonseed and linseed oil meal, the herd has been maintained on feed produced locally. For the past three years, alfalfa has been pastured with

dairy cows without loss. The North Platte Holstein herd has included the only Nebraska cow, Beauty Girl Gerben Rebecky, with a yearly fat record above 1,100 pounds. She has made two such records. A world's champion long-time milk producer, with a record of 227,832 pounds of milk and 8,455 pounds of butterfat produced in 10 lactation periods, was La Vertex Quantity of U Neb, member of the herd at Lincoln. The production is equal to 148 times the weight of the cow. She averaged 7.7 gallons of milk per day for ten months of the year for a period of ten years.

Extensive studies have been made on the influence of number of daily milkings on production, and the conclusions have shown that three and four daily milkings are profitable, with better cows. Much of the work with the herd has been done by R. F. Morgan. In recent years studies on reproduction, with the aim of improving herds through breeding, have been conducted. Like many other projects this is part of a nationwide activity in which considerable attention is given to artificial insemination. A satisfactory method would increase the number of animals with high-producing ancestry.

Readings In Dairy Science

On the subject of feeding, Morrison's "Feeds and Feeding" is a standard work, but there are many other interesting and valuable books on the subject of dairy management, for example, Fraser's "Dairy Farming" (John Wiley and Sons, 1930); Eckles' "Dairy Cattle and Milk Production" (Macmillan, 1929), Henderson's "Dairy Cattle Feeding and Management" (Wiley, 1928), and Davis, Wermelskirchen, Dickinson, Coffey, and Misonger's "Livestock Enterprises" (Lippincott, 1937). There are also general books on dairy manufacturing.

Among publications of the Nebraska College of Agriculture, the following are of greatest interest: Extension Circulars 621, "Feeding Dairy Cattle"; 622, "Dairy Calf Care and Management"; 625, "How to Produce Better Milk and Cream"; and 626, "Selection and Care of Dairy Sires"; Experiment Station Circulars 53, "Babcock Testing and Other Methods of Analyzing Dairy Products"; and 54, "Judging Quality in Dairy Products."

The results of work on vitamins, growth, Bang's disease, and number of daily milkings are published as Research Bulletins, which are of interest chiefly to technical workers. Bulletin 303, "The Manufacture of Neufchatel and Cream Cheese," is of interest to creamery managers.

Among the Farmers' Bulletins of the U. S. D. A. are several devoted to dairy feeds, dairy management, and dairy manufacture.

Cattle Feeding

WHEN WE go back to 1880 we discover that on the University farm there were few cattle, and among them there were no Herefords or Holsteins, the major breeds of today. The managers had a few animals of several breeds and hoped from these few to make some satisfactory observations on the adaptability of breeds for both milk and beef production. Farmers were as much interested in breeds as they were in varieties of crops. In the course of time a few breeds have proved their superiority and have come to dominate.

There was, of course, an interest in feeds. Perhaps the most interesting part of the early work on feeds, from the point of view of a present-day feeder, is the silo built in 1882—22 feet long, 12 feet wide, 10 feet deep, walled with brick and timber. In all essentials it was like the popular trench silo of today and it proved successful and was recommended then, as today, for its value in conserving an excellent type of feed. Sorghum came to be recognized as an excellent crop because of its resistance to drouth. The Station report of 1897 mentions the installation of the first chemical laboratory for the analysis of feeds.

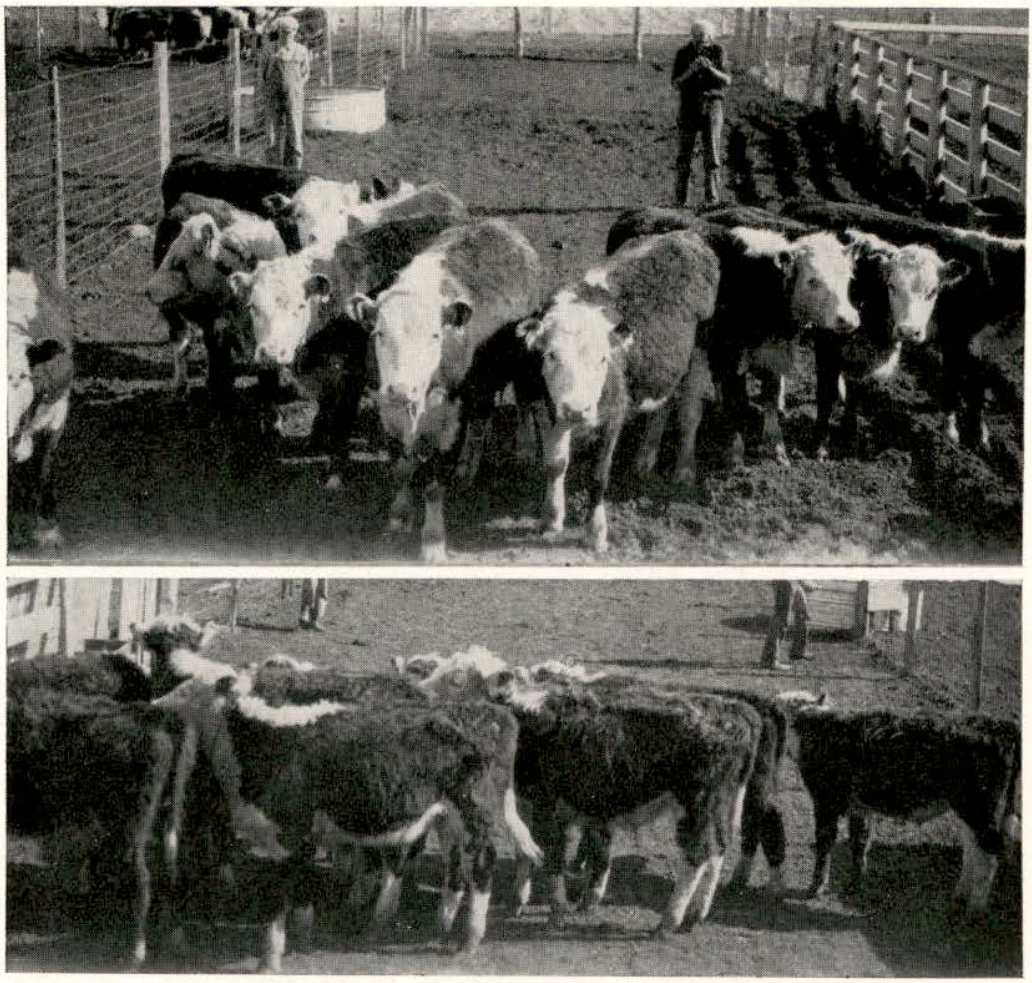
The period before 1900 might well be referred to as the pre-alfalfa period—the period before modern feeding trials had been developed, and before the great importance of alfalfa and other high-protein feeds used in conjunction with corn and other cereals was realized. The first cattle-feeding trial was begun in 1897, conducted by C. H. Elmendorf, head of the newly created Department of Animal Husbandry, and the test was designed to study the feeding of alfalfa and corn stover with various combinations of grain and roots. The following year E. A. Burnett became chairman and the first series of tests on alfalfa hay, sorghums, prairie hay, and grains was begun and completed in 1902. At about the same time similar tests were being conducted elsewhere. All of these tests pointed out the superiority of alfalfa and other legumes as forage.

Almost an unlimited number of questions arise, immediately after a feeding trial is completed. If it is admitted that the tests show the superiority of a particular ration, then to what extent may a feeder substitute cheaper feeds for those more costly? What is the influence of age upon the rate and efficiency of gains? What influence has sex? What effect has a ration on the quality of meat? The chief problem is to find, among Nebraska crops and other feeds that may be bought cheaply, the best combination, the best type of animals to feed it to, and the best time to feed it. For that reason, feeding tests have ordinarily been run over a series of years. This system makes it possible to average certain

results over long periods. In addition information on new feeding problems is brought forward during each year. In the course of time, feeding practice has tended to stabilize. As in other experimental work, single trials become a part of a plan and the work of a single experiment is merged into a body of general facts which have broad experimental proof to support them.

E. A. Burnett, who took charge of work in animal husbandry in 1899 and in 1901 became associate dean of the Industrial College and director of the Experiment Station. He served a long period as Dean and Director and ten years (1928-38) as the University's chancellor.

In 1904, E. A. Burnett and H. R. Smith reported their earliest work on high-protein feeds such as cottonseed meal and linseed oil meal. These were found capable of increasing gains, if fed in small quantities along with corn and prairie hay. As the experimental trials were continued, information on a wide variety of native and imported feeds increased. Developments in manufacturing have stimulated greater use of numerous



Feed lots at the Valentine Substation. Above: Lot fed mixed hay (rich in protein), 155.5 pounds of gain in 150 days. Below: Lot wintered on prairie hay alone, 25.3 pounds of gain per head in the same length of time. This is one of the numerous tests that have shown the value of proteins.

by-products. At one time the molasses by-product of sugar beet manufacture was allowed to flow into any convenient stream or ditch. It is now used as a livestock feed. In years of drouth and feed shortage, corn silage—even that made from stalks with no ears—has proved a useful feed when properly supplemented.

Following the World War the livestock industry was affected by many changes, such as the decline in foreign trade, overproduction of certain products, and changing demands of consumers. In meat production as in the production of flour it became necessary to meet consumer demands and to recognize finer grades of quality. With the increasing standardization of feeding practices, competition had become keener, production higher, and margin of profits narrower.

It was apparent that further improvements were possible. Two questions were the influence of age and sex of cattle. H. J. Gramlich accordingly began a series of experiments in 1920 to compare the feed-lot efficiency of

cattle of different ages and sexes. These tests demonstrated conclusively the superiority of younger animals in efficiency of production. Calves are more efficient than yearlings, and yearlings more than two-year-olds. The work on sex did much to overcome packer and consumer prejudice against heifer beef and thus enlarged the possibilities for both the grower and the feeder of cattle. Nebraska's cattle production is now almost entirely on a cow, calf, and yearling basis.

The change to younger animals and more intensive production has, however, heaped on the cattle producer many new problems. Beginning in the mid-twenties (1926), the Valentine Substation attacked the problem of wintering cattle in the sandhill section. These tests of protein supplements such as cottonseed cake and linseed oil meal, used with native hay, have reduced the cost of production, increased calf crops, and made possible the production of better cattle. With the change in demand from older to younger cattle, it became profitable to winter calves with rations better than prairie hay alone. Mixed clover hay and small amounts of supplement have proved economical. If cattle are to be summer-grazed rather than sold to feeders, supplement enough to make a pound a day of gain has been found economical.

At the North Platte Substation, in tests begun in 1904, grazing and wintering work with various ages have shown the superior value of alfalfa, as all or part of the ration, in wintering. Both yearling and two-year-olds lost weight when fed cane, or half cane and half prairie hay. Both a full and a half ration of alfalfa have resulted in gains during the winter.

Extensive work in more recent years at North Platte has shown (1) that full-feeding cattle on alfalfa pasture is economical and practical under southwest Nebraska conditions, (2) that an equal-parts mixture of corn and wheat or corn and rye is about equal in value to corn, when fed with alfalfa hay to calves, and (3) that wheat may be fed successfully as the only grain to fattening calves. Four years' work indicates that feeding well-wintered calves on native pasture is a practical method. Creep-feeding calves born in March and April has also proved beneficial and practical.

In 1929 a series of trials was begun at Lincoln with corn silage, corn fodder, the sorghums, and other roughages. Rough feeds are produced in abundance on Nebraska farms and the broad aim was to determine in each case the best method of using them. As supplements, cottonseed cake, soybean meal, linseed oil meal and others have proved valuable at certain price levels, in comparison with alfalfa hay. Other variations have included classes and ages of animals, winter and summer feeding, mineral nutrition, and feed preparation. During the recent drouth, molasses as a substitute for corn has been tested and evaluated.

Especially significant has been the evaluation of these feeds on the "per acre" basis. It has been shown, for example, that shelled corn, corn fodder, corn silage, Atlas sorgo fodder, and Atlas sorgo silage rank in the order named in beef production per acre, with shelled corn lowest and

Atlas sorgo silage highest. The difference between the two is about 300 per cent; that is, Atlas sorgo silage has averaged three times as much beef production per acre as shelled corn. These results are based on experiments conducted at Lincoln. The crop yields used were averages over 11 years and the cattle used were calves being wintered. Properly supplemented the sorgos and the whole corn plant, preferably in the form of silage, have immense advantages.

These experiments have brought about some very important conclusions and have also influenced methods of cattle management to a marked extent. Because of these tests the cattle producer can see a closer relationship between the crops he can produce and the beef he will have to sell. He can buy supplemental feeds more wisely and with greater profit. Once the producer has centered his attention on the importance of yield per acre, he can manage his farm and his livestock enterprises with greater effectiveness.

At North Platte Marvel L. Baker has conducted the more recent feeding trials while E. M. Brouse has been in charge at Valentine and R. R. Thalman at Lincoln.

References on Cattle Feeding

For a study of the principles underlying the feeding of all farm animals one should consult Morrison's "Feeds and Feeding" (Morrison Publishing Co., Ithaca, N. Y.). This is a standard work, widely recognized as thorough and sound. It brings together the results of feeding and management tests from all important sources. An abridged edition is available. Other books of interest are Edmonds, Carroll, Kammlade, Nevens, and Snapp's "Producing Farm Livestock" (John Wiley and Sons, N. Y., 1937), and Davis, Wermelskirchen, Dickinson, Coffey, and Misonger's "Livestock Enterprises" (Lippincott, N. Y., 1937).

Some of the Nebraska bulletins and circulars are Bul. 252, "Sex and Age as Factors in Cattle Feeding"; Bul. 274, "Contract Feeding"; Circular 58, "Feeding and Care of Calves"; and Extension Circular 238, "Feeding Small Grains to Livestock." A number of other reports are available and lists may be obtained. Among the Farmers' bulletins of the U. S. D. A. are many that deal with the management of cattle.

Swine Feeding

IN 1887, when the Nebraska Experiment Station was founded, there were more than two million hogs in the state which were worth somewhat more than 13 million dollars. On the whole, swine have been the chief livestock enterprise ever since. At that time corn was a major crop, as it is today, and hogs were then, as now, the chief means of marketing corn.

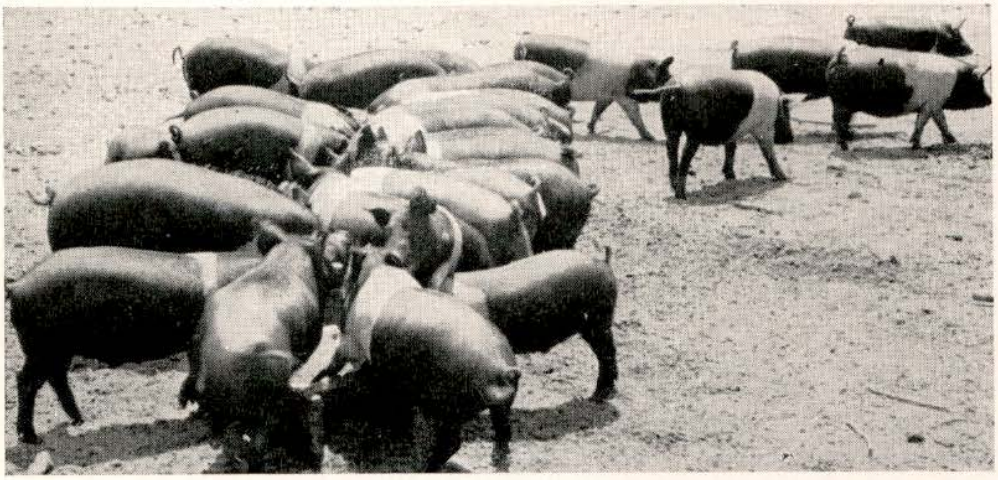
Before there was an organized experiment station in the University of Nebraska, an attempt was made on the farm to determine whether or not soaked corn was superior to dry corn as a feed for hogs.[1] Three lots of two pigs each were used. One lot was fed dry corn and water, another soaked corn and water, and the third soaked corn, "green corn, weeds, swill from the house without milk, salt, copperas, etc." The pigs were

[1] This experiment is described in the "Report of Experiments at College Farm," Uni. Nebr., 1880.

weighed regularly and records were kept, but the results were enough to baffle the investigator, as anyone acquainted with recent developments in animal nutrition might suspect. One pig became sick and all became restless, according to the report, and in general the results were inconclusive.

It is perhaps unnecessary to point out that an experiment of this sort had its value. Years later, work of a similar sort in another state experiment station—an experiment more carefully observed and more prolonged—led to the discovery that certain feeds lack vitamins which are essential to health.

As in cattle feeding the earliest important fact developed by state experiment stations in the Corn Belt was that of the high value of alfalfa or other legumes. With the growth of alfalfa acreage, hog pastures were fenced off adjacent to hog pens and alfalfa grew here as long as the stands lasted. Other pasture crops have been used and are being used—notably sweet clover, sudan grass, rye and others in rotations. The plan of keeping hogs on pasture—even of having them farrowed there—fits in



Healthy, thrifty swine return high profits in Nebraska.

well with a sanitation program, which through long farm experience has been found profitable, especially in view of the fact that hogs in crowded quarters are ready victims of disease germs and parasites. Turning hogs into corn fields to "hog down" the corn has also proved advantageous.

The early work with hogs, under the direction of E. A. Burnett and H. R. Smith, showed that wheat, especially if ground or soaked, will fatten hogs and may be used under certain price conditions, and that tankage saves corn and increases the rate of gain. At this time tankage, a by-product of meat packing, was coming into prominence. Breaking tests with bones showed that the absence of sufficient protein and minerals in the ration weakened the skeleton of the pigs.

In 1904, W. P. Snyder at the North Platte Substation embarked upon 26 years of comprehensive experimentation to "determine the most profitable method of producing pork with the use of alfalfa and to test the

feeding value of grains commonly grown in the country." His work on alfalfa hay, alfalfa meal, and alfalfa pasture in various phases of swine production is commonly regarded as the most comprehensive work done in the country on that subject. In addition cost of production at various ages, feed-lot value of wheat, rye, barley, emmer, proso, shorts, and sorghums, comparative value of white and yellow corn, hand feeding as compared with self-feeding, methods of preparing hog feeds, full rations in comparison with limited feeding, and comparisons of protein supplements have also been included in his work.

In a comprehensive manner experimentation with feeds and management practices has kept pace with the swine industry on the one hand and with the developments in nutritional science on the other. At the central station swine feeding investigations have been under the direction of Wm. J. Loeffel since 1919. In the later years, feeds such as soybean oil meal, sudan-grass pasture, molasses, and sorghum grain have been under test. In 1925, with the growth of interest in vitamins and the rickets-preventing factors in feeding, a study of the absence of sunlight or vitamin D as supplied in cod-liver oil showed that rickets could be readily induced in swine. Such work in addition to the work of other stations in other states has surrounded the swine industry with safeguards that make for stability.

Briefly stated the most general conclusions regarding the hog industry in Nebraska as proved and demonstrated by the Station and exemplified in farm practice are as follows: There is more difference between individuals than between breeds. Pasture and forage crops reduce feed costs and improve the health and thriftiness of hogs. The self-feeder is a sound practice where rapid gains are desired. With corn as a base (100 per cent) other grains rank as follows in pounds of grain required per unit of gain: oats 70, ground rye 85, ground barley 85, grain sorghums 90, wheat 108. Protein supplements play a definite part in economical production. Control of diseases and parasites is essential.

References on Swine Feeding and Management

Everyone who has an opportunity should become familiar with Morrison's "Feeds and Feeding," which deals with all types of livestock. Another valuable book is W. W. Smith's "Pork Production," (Macmillan, 1937). Two Nebraska publications are of fundamental importance: Circular 39, "Swine Sanitation," and Circular 40, "A Manual for Hog Raisers."

Sheep Feeding

SHEEP rank below hogs and cattle as livestock enterprises in Nebraska, but in lamb feeding Nebraska ranks second in the United States. Consequently lamb feeding and farm flock management have occupied an important place in the experimental program at the station at Lincoln and also the Scottsbluff substation, which is in the North Platte valley where sugar-beet by-products are plentiful.

The early sheep-feeding experiments were conducted to compare the value of rations available for fattening range lambs for market. Corn, oats, bran, linseed meal, and alfalfa, prairie, and sorghum hay were among the feeds tried and E. A. Burnett reported in 1900 that alfalfa-fed lambs made gains slightly more than 50 per cent greater than lambs fed prairie hay with the same grain ration. Linseed meal, a high-protein supplement, increased the gains substantially when added to a ration of corn and prairie hay. Experiments conducted later by H. J. Gramlich demonstrated that corn silage is a good lamb feed if fortified with a protein supplement and that lambs can be fattened by turning them into a field of corn. In the course of time, most of the various protein supplements available have

The trench silo is an excellent means of storing forage.

been evaluated in lamb-feeding trials, but alfalfa hay, chopped if coarse, has proved to be the most practical source of protein in Nebraska lamb-feeding areas.

Lamb-feeding experiments have been the principal livestock work at the Scottsbluff station, and ascertaining the value and place of local feeds in lamb-fattening rations has been the main object. The conclusions may be summed up as follows:

Dried beet pulp is about 80 per cent as valuable as corn for fattening lambs.

Barley is equal to dried pulp.

Plain dried pulp is equal to molasses dried pulp.

Sugar-beet tops reduce both the concentrates and alfalfa necessary.

Corn silage has no marked effect on gains but takes the place of some of the alfalfa hay.

Cull potatoes are only slightly more valuable than corn silage.

Usually the addition of a protein supplement to a lamb-fattening ration which allows the lambs all the good alfalfa hay they can consume is a doubtful practice, but whenever the alfalfa hay is limited or is excluded from the ration, the addition of a protein supplement is imperative.

This information is used widely in the North Platte valley where from 200 to 500 thousand lambs are fattened annually. The farm flock for eastern Nebraska farms has been studied experimentally at Lincoln and has been found feasible—especially if early spring lambs can be put on the market before the late-spring decline in prices.

For Nebraska flock owners the following general principles have been proved and demonstrated: To be worthwhile a flock should contain at least 30 to 35 ewes. Aged western ewes may be profitably used to establish a farm flock. Production of lambs for the early spring market is feasible on Nebraska farms. It is necessary to use grain in order to produce lambs for the spring market. All farm flocks must be treated for stomach worms. Poor feeding produces poor wool and poor carcasses.

For several years A. D. Weber conducted studies of sheep feeding and management at Lincoln and in recent years M. A. Alexander has been in charge.

References on Sheep Feeding and Management

Circular 48, "Farm Sheep Facts," is a fundamental Nebraska circular. "Feeds and Feeding" is a standard book.

Studies of Meat Quality

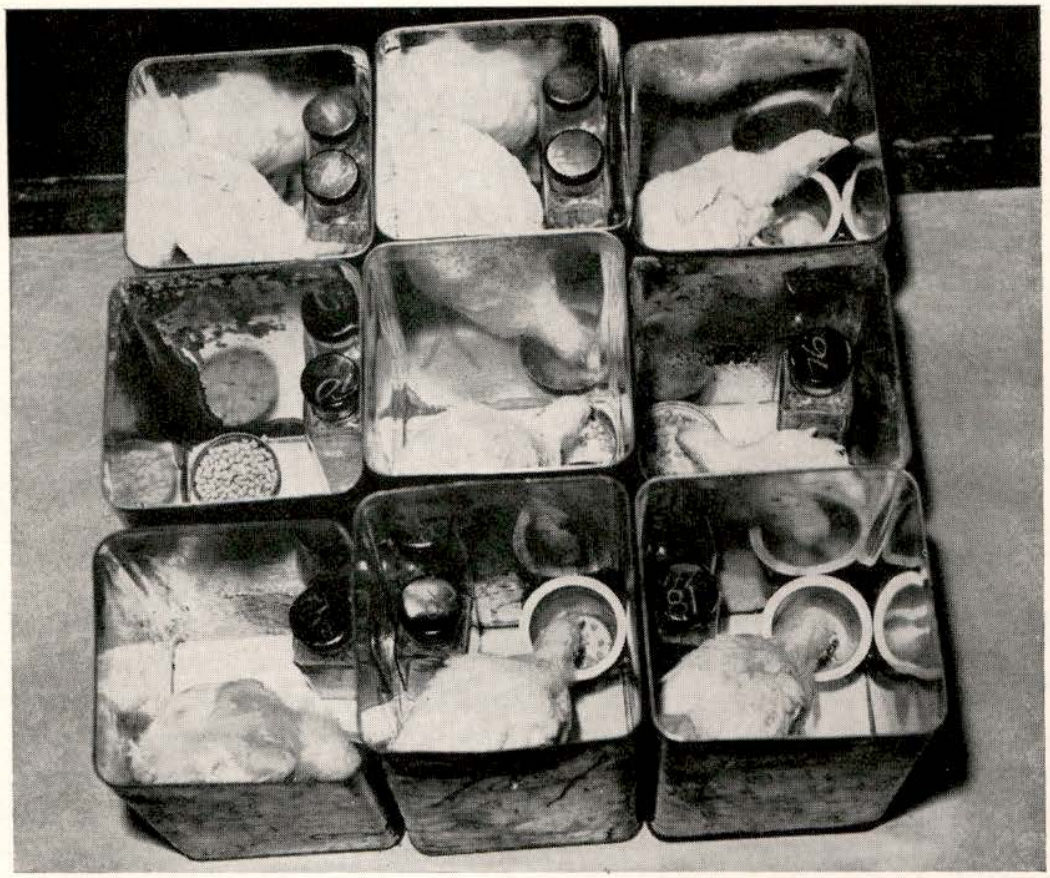
STUDIES of meat quality have been conducted in recent years not only in the Nebraska Station but in a number of stations in co-operation with the U. S. D. A. Consumers are of course very much interested in the quality of meats and the question of quality is of importance to the feeder because of the direct relationship of quality to feeds.

As early as 1915, demonstrations of meat quality were conducted for the benefit of students and in 1919 a laboratory for meat study was established. Investigations in 1926 showed the comparative qualities of heifer and steer beef of the same age when similarly fed. Age as well as sexes were compared and the result has been an increased popularity of baby beef and a decline in prejudice against heifer beef.

Studies of carcasses have shown the high quality of meat produced with wheat, rye, barley, molasses, and grain sorghum. Tests have also been made with supplementary feeds and it has been shown in Nebraska as well as in other states that soybeans, if fed extensively, will produce "soft" pork which is of low market value. These studies have important relations to feeding problems and help to answer such questions as the following: How long to feed? What weight should animals be fed to? What age of calves make the best veal? As a part of these studies, cooking tests are conducted.

Poultry Feeding and Management

ON MOST farms chickens, turkeys, and other poultry are subjected to more careful management now than they were thirty years or forty years ago. Along with the realization that cattle, hogs, and sheep would respond, with greater profits, to improved management came the realization that poultry, if carefully protected against disease and if carefully fed and marketed, could become something besides an unprofitable but necessary sideline. Farmers in Nebraska raise about twenty-four million



Chicks being used in a carefully controlled feeding experiment.

chickens annually, or an average of about 175 per farm. This is about 4 per cent of the nation's total, and in addition Nebraska farmers raise about 2½ per cent of the nation's turkeys.

Experimental work with poultry was not begun until 1915 when a flock of 600 hens was obtained, including Barred, White, and Partridge Plymouth Rocks, White and Partridge Wyandottes, Single and Rose Comb Rhode Island Reds, Single Comb Buff and Single Comb White Leghorns, Black Langshans, Light Brahmas, and Anconas. As with crops and livestock, the early work involved the selection of the most suitable kinds for Nebraska. Trap-nest records of the birds showed a variation of from 2 to 275 eggs per hen per year. Culling out of poorer birds raised the

number of hens with records of 200 eggs or more per year from 33 such birds in 1919-20 to 86 birds in 1922-23. Distribution of breeding stock from the Station's trapnested birds to farm poultry raisers and poultry breeders was carried on for a few years following 1917.

Inexpensive housing and sanitation have been important aims of the work with poultry and it has been found that insulation with materials available on the farm is profitable. Experiments with floors have shown that concrete floors of not over one inch in thickness are satisfactory from the point of view of wear and sanitation. The use of artificial lights has increased egg production during December, January, and February. Artificial heat and expensive ventilating systems have been found impractical, as have fans for stirring the air. Sanitation—carefully applied in housing and construction of equipment—has proved to be a matter of utmost importance.

The earliest test on feeding at the Nebraska station showed that no single grain is at all adequate for normal growth. After considerable experimentation directed by F. E. Mussehl, combinations of feeds have been worked out which are made up chiefly of Nebraska-grown products. The results of years of tests of poultry rations have gone into the preparation of the Nebraska All-Purpose mash, commonly called Formula 8. The ration has come to be widely used and is constantly being improved. Variations of it are shown in the following table.

NEBRASKA MASH FORMULAS

Formula 8 and Variations

Ingredients	All-purpose Mash			Turkey starter No. 8 TS	Breeding flocks
	No. 8	With skimmilk No. 8 M	With soybean oil meal No. 8 S		
Yellow cornmeal	310	410	310	250	210
Shorts	200	200	200	200	200
Bran	100	100	100	100	100
Pulverized barley or whole oats	100	100	100	100	100
Alfalfa meal (No. 1)	100	100	100	100	200
Meat scraps (55% protein)	50	25	50	70	50
Fish meal (65% protein)	50	25	50	70	50
Dried buttermilk	50	..	..	..	..
Soybean oil meal (43% protein)	..	..	50	70	50
Oyster shell or limestone (chick size)	20	20	20	20	20
Fine salt	10	10	10	10	10
Suitable fish oil	10	10	10	10	10
	1000	1000	1000	1000	1000
Approximate protein content (%)	18	15	19	22	19

Variations from Formula 8 are readily made, in accordance with conditions of price and supply. During the recent years of drouth a ration

without corn was devised and widely used; the deficiency in corn was made up by an increase in the proportions of shorts and bran. Here, as in the feeding of other animals, the protein portions are important, because they are not found in sufficient quantities in most Nebraska crops, with the exception of legumes such as alfalfa. Proteins are available in by-products of various manufacturing processes such as meat packing, dairy manufacturing, processing of fish, and milling. Soybean meal, linseed meal, and cottonseed meal are common protein supplements. Fundamental studies on the proteins and protein levels of intake of chicks have been conducted by C. W. Ackerson. Such studies serve to evaluate feeds in various combinations. In actual practice the protein concentrates and other portions that are purchased may be mixed separately and fed in the proper proportions. The choice of a feedstuff and the combination of feedstuffs in economical proportions are of first importance in the problem of making a profit from poultry.

Readings In Poultry Science

There are several good general books on poultry management: Jull's "Poultry Husbandry" (McGraw-Hill, 1930); Rice and Botsford's "Practical Poultry Management" (John Wiley and Sons, 1925); and Lippincott and Card's "Poultry Production" (Lea and Febiger, Philadelphia, 1934).

Some of the results of work at the Nebraska Station are contained in Extension Circulars 1463, "Poultry Feeds and Feeding" and No. 1410, "Essentials in Turkey Raising." A number of others have been prepared and are available. Ask for a list.

Agricultural Engineering

AGRICULTURAL ENGINEERING as a separate and distinct type comparable to electrical and civil engineering was not recognized until about 30 years ago. At that time the courses leading to degrees in agricultural engineering were first provided in American colleges and the Nebraska College of Agriculture was one of the first to take steps in the direction of providing training.

In Experiment Station work little that could be classified as agricultural engineering was done prior to 1920. The earliest bulletin of the station, which dealt with irrigation, was written by a geologist. The early station workers made some observations about the success or failure of new farm machinery and certain types of farm buildings, but in a general way agricultural engineering was a neglected science until the second decade of this century.

The expenditures for machinery and buildings have come to be almost the chief items of expense on farms. It sometimes happens that more money is spent on equipment and buildings than the farm income has justified. Management of farm equipment and buildings is a matter that involves considerable time and expense. In a general way, the coming of motors and large-scale machinery has brought agricultural engineering to the fore among agricultural sciences. Engineering in agriculture is fundamentally an application of principles of construction, electricity, and mechanics to farm conditions.

A major feature of the Experiment Station work has been the testing of tractors, which was begun in 1920 as a result of an act of the state

A tractor test under way.

legislature. This act made it necessary for all tractor models to be tested before they could be sold in the state. Tests cover belt and drawbar performance, including fuel economy, power developed, and other characteristics. Over 300 tractors have been tested and about a third of these are still on the market at the present time. The Nebraska tractor tests have become standard the world over, for this is the only testing station of its kind. Some experimental work has been done on pneumatic tires for tractors, on tractor lugs, and other tractor parts.

Another important project has been the project on rural electrification, which was organized in 1926. Under this project, extensive surveys have been made and data on costs of operation and performance of electrical equipment have been obtained. More intensive work has been done on certain pieces such as water pumps, water heaters, soil heaters, and others. This project has been under the direction of E. E. Brackett, E. B. Lewis, and F. D. Yung.

At the North Platte Substation, a pump irrigation plant was established in 1918. Records on the installation have been kept up to the present time. Potatoes, alfalfa, and corn are the chief crops irrigated. Since 1925 power has been supplied at this pumping station by electrical motor.

Readings In Agricultural Engineering

Books of value to anyone interested in agricultural engineering would be concerned with the several phases of that subject—for example, farm buildings, tractors, and farm motors. Such books include Smith's "Farm Machinery and Equipment" (McGraw-Hill, 1937); Davidson's "Agricultural Machinery" (John Wiley and Sons, 1931); Foster and Carter's "Farm Buildings" (Wiley, 1928); and Wooley's "Farm Buildings" (University Cooperative Bookstore, Columbia, Mo., 1936). The following are of fundamental value in irrigation: Israelsen's "Irrigation Principles and Practices" (Wiley, 1932); Harding's "Operation and Maintenance of Irrigation" (McGraw-Hill, 1917); Etcheverry and Harding's "Irrigation Practice and Engineering, Vol. 1, Use of Irrigation Water and Irrigation Practice" (McGraw-Hill, 1933).

The Extension Service at the Nebraska College of Agriculture has a large list of circulars dealing with farm mechanics and range from rope tying and forge to surveying, terracing, and care of machinery.

The Experiment Station publishes annually a report of the tractor tests. The number of the tractor test bulletin is changed from year to year, but the bulletin itself is fundamentally the same except for the addition of reports of new tractors tested and the elimination of reports of tractors no longer on the market. Station Bulletin 282, "Pump Irrigation Investigations in Nebraska"; Bulletin 301, "Pump Irrigation at the North Platte Substation"; and Extension Circular 754, "Pump Irrigation," are publications of particular interest to those concerned with these problems. Among Farmers' Bulletins of the U. S. D. A. are several on general problems of irrigation.

Studies of Economic Conditions

DURING the first twenty-five or thirty years of the history of the experiment stations in the United States the aim of the experimental work was almost exclusively that of increasing production, of making two blades of grass grow in place of one. But more recently, or since the close of the World War, the objectives of the Station have included, in addition, better management in production, better marketing, and a better understanding of the forces that affect economic and social conditions. The Purnell Act, passed by Congress in 1925, increased funds for such work, both in the state stations and in the U. S. Department of Agriculture.

Economics as applied to farming is a study of the factors, in addition to crop production, livestock production, and disease and pest control, that influence the purchasing power of farmers. It is one thing to improve crops, livestock, and equipment; and it is still another thing to do so profitably.

Production is related directly to consumption and consumption is directly related to purchasing power. Consequently in Nebraska, as elsewhere, the purchasing power of farmers—that is, the relationship of the value of goods sold to value of goods purchased—has been a matter of concern on the part of economists. In a general way, purchasing power has fallen from higher points preceding the year 1920 to lower points since. Prior to 1920, purchasing power was increasing gradually, with minor variations from year to year, just as there have been minor variations since 1920. The effects of inflation and deflation for the period 1914 to 1934, so far as Nebraska farmers are concerned, have been described by H. C. Filley, chairman of the Department of Rural Economics, in a bulletin published in 1934. In this research bulletin, the long-time changes in purchasing power have been set forth.

There may be said to be several means of increasing purchasing power of a farm family. One of these is improvement in management of the individual farm. The men who in the late 1870's and early 1880's were conducting experiments on the University's farm kept records of the costs and labor required to perform the tasks, so that farmers could judge the project from the standpoint of management. In 1893, C. L. Ingersoll, director of the Station, and S. W. Perin, foreman of the farm, reported the costs of producing several crops. Professor C. W. Pugsley began, in 1909, the teaching of farm management in the agricultural college. Before this, Professor E. G. Montgomery, a specialist in field crops, had given lectures on the subject. From this beginning, interest in management

grew, so far as college teaching was concerned, and eventually marketing was added to the courses. At the same time, the Office of Farm Management of the U. S. Department of Agriculture was growing and conducting surveys in Nebraska. The survey method was soon supplanted by the farm account book.

It is impossible to estimate the value of the farm account book to Nebraska farmers. In the almost twenty years since its use was begun, thousands of farmers have used it. It is a simple and complete method of keeping farm accounts and not only provides a complete business record for the farmer but also, when turned in at the College of Agriculture, becomes a source of information regarding prosperity on various types and sizes of farms, and the success of various management practices. In addition many farmers have kept cost-of-production records on one or more crops such as wheat, corn, and potatoes, and also cost-of-operation records on machines such as tractors and combines. The record keeping is supervised by representatives of the Extension Service.

From surveys made during the years 1912 to 1915, H. C. Filley obtained material for a report in 1916 which showed that 80-acre farms of eastern Nebraska were too small to utilize labor and machinery as efficiently as larger farms. The more successful farmers were also obtaining yields of from 15 to 30 per cent larger than the less successful, and they were also selling two to three major and two to four minor products, as compared with fewer products for the less profitable farms.

In 1926 and again in 1928, reports by Harold Hedges were made on studies of ranch management in the Sand Hills. In these studies the value of efficient handling of credit and obtaining good calf crops, protecting pastures against overgrazing, and in marketing calves well was apparent. Credit had become burdensome in many instances as a result of over-expansion following the war. The ten best ranches studied were returning from 5.4 to 15.4 per cent annually on the operator's equity, while the ten poorest ranches were returning from a minus 2.8 to a plus 4.3 per cent.

As a means of studying farm management, much use has been made of the area plan. That is, certain areas—thirteen in Nebraska according to the most recent classification—are determined in which, for best returns, the type of farming is, and probably should be, fairly uniform. The first study of this sort was by R. R. Spafford in 1919. In 1930, another was made by Harold Hedges, in collaboration with F. F. Elliott of the U. S. D. A. The latest study of this type was made by L. F. Garey. Climate, topography, soils, distances to trading centers, prevalence of pests and diseases, and other factors determine the boundaries of these areas and it is of importance for the farmers as individuals and as communities to understand the purposes for which their areas, as well as their own farms, are best suited. In his recent study L. F. Garey has shown that in most of the Nebraska areas soil-conservation practices, such as increase in legumes and grasses or fallowing, would result in the production of as much livestock feed as under the systems in operation, and in many areas more would be produced.

Improvement in the farmers' purchasing power can also be obtained to some extent through care in marketing. Several studies have been made in Nebraska, and here as elsewhere there has been a noteworthy increase in cooperative marketing. During the years 1923 to 1933, H. C. Filley and Harold Hedges, assisted by others, made some studies of the price-making forces affecting Nebraska farm products and each year the Department of Rural Economics prepares information on the outlook for prices in Nebraska, in cooperation with the Bureau of Agricultural Economics of the U. S. Department of Agriculture. Many factors enter into the making of prices and the influence of each factor is continually changing. Consequently economic forecasts are subject to contingencies. They do, however, play a part in directing farm activities away from those that are likely to be overdone in a particular year and thus make some contribution toward stability and evenness in production. Many farmers, through a study of market demands, have been enabled to meet those demands more effectively. In the marketing of many products, cooperative methods have aided in reducing marketing costs. Turkeys, for example, when cooperatively marketed are graded according to quality, and thus the producer has the advantage of selling a graded product.

Besides the studies in farm management and marketing, the Nebraska Station has made some other studies related to farm purchasing power. One of these has been a study of taxation of farm properties. Others have been studies of farm mortgages and land prices in selected areas. Credit and taxes are important expense items that are charged against the farm business, and information of this sort is of value to political officers as well as the general public. In 1933 the Nebraska College of Agriculture, in response to demand of taxpayers, printed a series of twelve Extension circulars on taxation, which were prepared not to report research but to present information.

With the increase in economic studies during the 1920's came also an increase in studies designed to obtain information on general living conditions on Nebraska farms. An important question is the question of how tenure, size of farm, and other factors affect phases of living, such as housing, food, clothing, reading matter, and other home or community activities. Several bulletins by J. O. Rankin presented the results obtained from surveys during these years. Closely related information has also been obtained by the home economists of the Extension Service from year to year through the use of a home account book, which is similar to the farm account book, and in 1934 home economists of the Station staff completed a study of living conditions during the years 1931-33.

Some conclusions can be drawn from this work. Farm tenancy has increased continuously since the beginning of the century and has reached about 50 per cent. Nebraska farm families have about the same standards of living as have those in other states. Improvements in homes, such as running water and electric lights, have been coming slowly, but they have shown a continuous increase. At the same time, however, there has been

some decline in the value of all goods used for living on Nebraska farms in the period since studies were first made. The average "value of living" which includes the home-produced as well as purchased commodities, was found to be $1,600 in 1923-24 and ten years later in a similar study it was about $1,000. Changes in prices explain some of the difference, but decline in purchasing power of farm products is largely responsible. About two-fifths of the value of the farm living is produced on the farm; the rest is purchased. Among farms the variation in value of living is wide—from a few hundred to as much as four thousand dollars. In general, younger families spend less and older families more.

References on Rural Economics

Good books on general principles of farm management are Overton and Robertson's "Profitable Farm Management and Marketing for the Corn-Growing States" (Lippincott, 1936) and App and Waller's "Farm Economics: Management and Distribution" (Lippincott, 1938), and Hopkins' "Elements of Farm Management" (Prentice-Hall, 1936). For cooperative principles, one should consult H. C. Filley's "Cooperation in Agriculture" (John Wiley and Sons, 1929). There are other good books, of course, and one can obtain lists from the publishers. Several good introductory books on economics are available and new ones appear frequently. Noteworthy are the publications of the Brookings Institution, Washington, D. C.—for example "The Recovery Problem in the United States" (1936) and "America's Capacity to Produce" and "America's Capacity to Consume" (1934).

Among the Nebraska publications (available through county agents or the College at Lincoln) are the following: Res. Bul. 71, "Effects of Inflation and Deflation on Nebraska Agriculture"; the "Nebraska Tax Primer" (price 50 cents); Bul. 299, "Factors Determining Type-of-Farming Areas in Nebraska"; Bul. 309, "Systems of Farming and Possible Alternatives in Nebraska"; and Bul. 314, "Operating Problems of Farmers' Elevators in Nebraska."

The costs of producing the more important farm crops are reported annually in mimegraphed Extension circulars. The data are compiled from farm account books.

Science In The Home

FEW HOME managers now have failed to receive aid from the modern science of nutrition and from the sciences of engineering, chemistry, and economics as they have developed in the past fifty years. The farm woman of two generations ago was an artisan of no slight or mediocre talent. She preserved fruits, made clothing, made butter and cheese, baked, cooked, "cleaned house," reared children—all difficult tasks. Science has come to her aid.

Home-economics research is a comparatively new thing—first encouraged and made possible by the Purnell Act of 1925. Surveys of rural home conditions have been conducted in Nebraska—surveys of lighting, of farm kitchens, of facilities such as water supply, of foods used, of family expenditures, and of the kinds of work done. One of the later surveys, completed in 1933, showed variations among farm families in standards of living, and a study of relief activities in 1933 and 1934 revealed that prior to the coming of federal participation in 1934, the methods of adminis-

tration by county officials varied widely. Such surveys provide a better understanding of the problems of rural life. While no comprehensive summary of the findings of these surveys is possible in a short space, it may be said briefly that wide variations were found and aid in management provided through project and study clubs under the sponsorship of the Extension Service have helped, as has the wide dissemination of information on home management.

Among the home-economics research projects at the Nebraska Experiment Station have been several intensive studies of special problems, the results of which are of broad application, extending beyond the state itself. Such a study was the study of kerosene stoves conducted by Mrs. Edna B. Snyder and completed in 1930. Among the several types available on the market a few were found to be more efficient and more easily cleaned and kept in working order than others. Similar conclusions were reached for washing machines, and more recently studies of electric stoves, gas stoves, and household steam pressure cookers, by Arnold E. Baragar, have been completed. The results of these studies, which have dealt with types of construction and their relative value, have been available to manufacturers, dealers, and consumers, and they have contributed much to the home manager's knowledge of the modern complex equipment with which she works.

A few studies have dealt with foods—such as the recent studies of lard in cake making, the factors related to cooking quality in dry beans, and the relative costs of home and commercially prepared bread and rolls. New studies, recently inaugurated, deal with family-life relationships and the nutrition of adolescent girls.

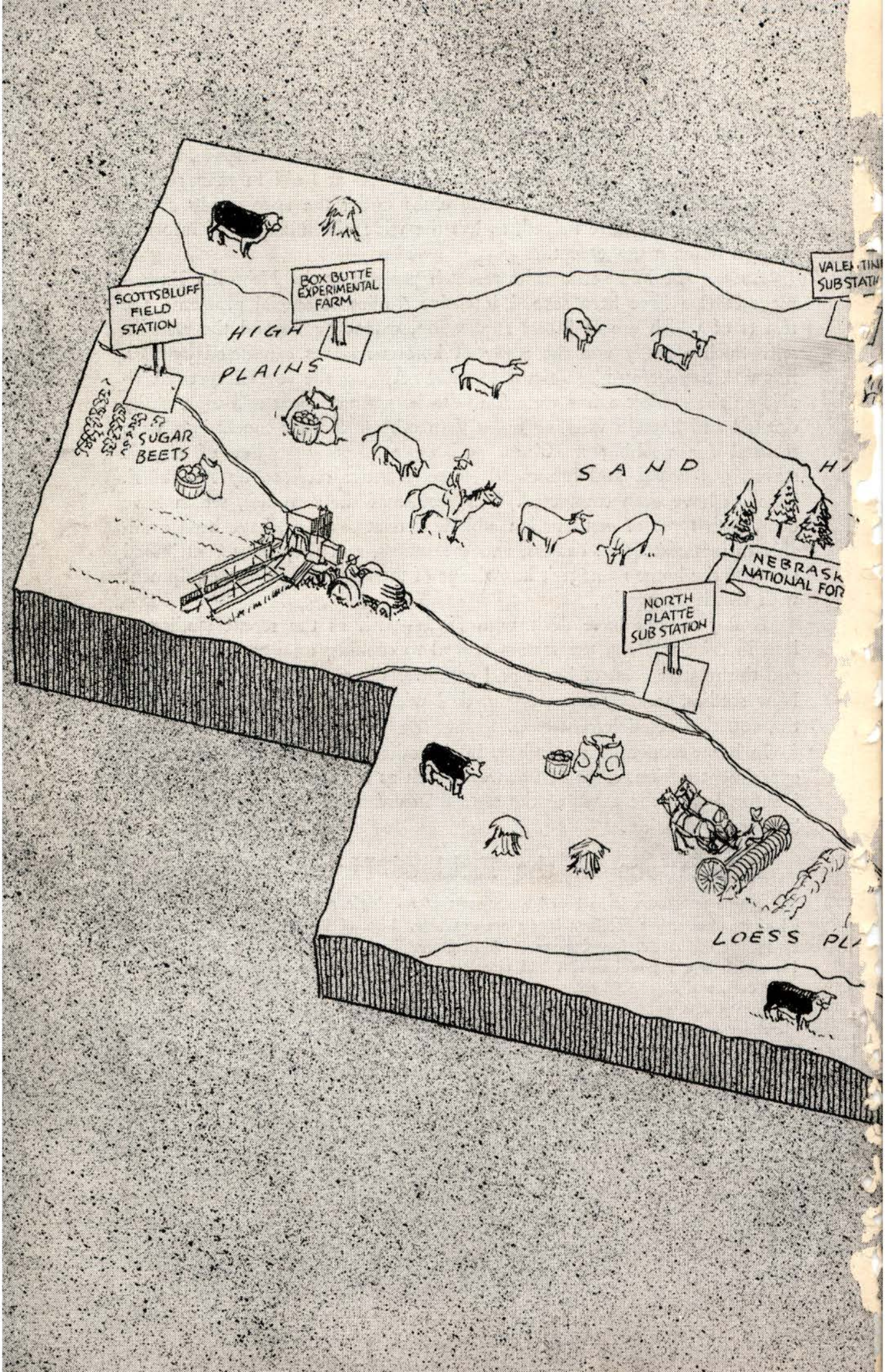
In home-economics research as in the other types conducted by a state experiment station, some of the work, such as the surveys, is more closely identified with the needs of the state than are other types—and some has broader application.

Publications In the Field of Home Economics

Home economics is so broad a subject that no single publication could deal with all of its phases, but excellent books are available. Lists of books have been published by the Extension Service, College of Agriculture. In addition, one may obtain Form 14, which is a list of bulletins and circulars on clothing, food, household equipment, child care, and other subjects.

The reports of the Nebraska Station investigations are listed here: Circulars 49, "Laundry Equipment and Methods"; 41, "Selecting and Management of Kerosene Cook Stoves"; 55, "Selecting Your Gas Stove"; 57, "Your Pressure Cooker." Research bulletins on the technical phases of the studies are also available, but these are of little interest to the nontechnical person.

Any home demonstration agent or county agricultural agent in Nebraska can supply circulars or lists of books, or one may write to the College of Agriculture at Lincoln.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BOX BUTTE EXPERIMENTAL FARM
HIGH PLAINS
SUGAR BEETS
SAND
NEBRASK NATIONAL FOR
NORTH PLATTE SUB STATION
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